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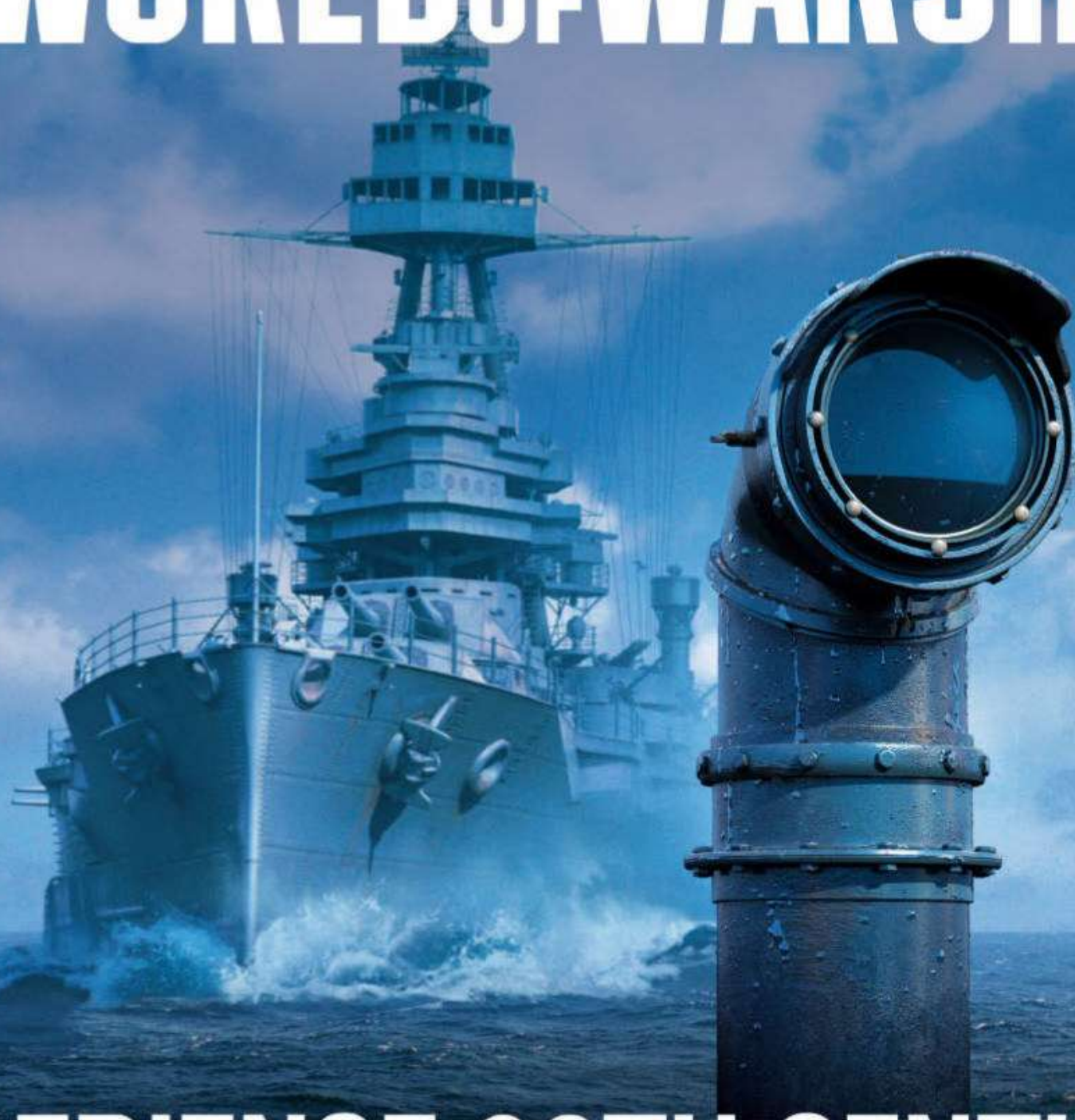
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COVID-19 has changed several aspects of our home planet



Welcome

This month **All About Space** investigates when we're likely to see first light at the

European Southern Observatory's (ESO) Extremely Large Telescope, or ELT, currently under construction in the dry, arid Atacama Desert in northern Chile. To get the best views possible the ELT will sit atop the Cerro Armazones mountain.

Currently ESO astronomers have revealed we're likely to see some kind of operational movement in 2025 where, as you'll discover this issue, the megastructure - which consists of a 39.3-metre (130-foot) diameter segmented primary mirror and a 4.2-metre (14-foot) diameter secondary mirror - will advance our astrophysical knowledge. I'm of course talking about furthering our studies of planets around other

stars, looking back to the very first galaxies in the cosmos, getting a better handle on dark energy and dark matter as well as uncovering any molecules that could point to life in other planetary systems - in particular water and organics. With the ability to gather 100 million times more light than the unaided eye and with a light-gathering capacity that's 256-times greater than Hubble - and 16-times sharper too - I for one am looking forward to what's likely to be a breathtaking view of the 'hidden universe'.

Enjoy the issue; there's plenty to keep you occupied - from the latest in space science news to observing advice. See you next month!

Gemma Lavender
Editor-in-Chief

Our contributors include...



Paul Cockburn
Science writer

What will happen on 'Earth's last day'? Can life find a way to survive? Paul sheds light on what will happen when our Sun swells into an engulfing red giant.



Lee Cavendish
Staff writer

How has the coronavirus pandemic impacted planet Earth? Lee's special report investigates the changes to the environment and how you can help.



Colin Stuart
Space science writer

Have we finally found out what's at the end of space and time as we know it? Colin speaks to the astronomers who might have solved an age-old riddle.



Lisa Harvey-Smith
Astrophysicist

Working in radio, Harvey-Smith talks about why observing in such a waveband reveals the cosmos like never before.

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LAUNCH PAD

YOUR FIRST CONTACT WITH THE UNIVERSE

06 Hubble's 30th birthday image is released, more 2I/Borisov discoveries and astronomers see ATLAS breaking up



FEATURES

14 **Rise of the super telescope**

As work continues on its design and construction, we take you inside the Extremely Large Telescope as it prepares for first light in 2025

24 **Space.com Water on Jupiter**

26 **Interview The wonders of radio astronomy**

Astrophysicist Lisa Harvey-Smith reveals how we're uncovering the hidden universe

30 **The last days of Earth**

In the grand cosmic scale of the universe, our planet is doomed. **All About Space** finds out what will occur during our planet's final moments

38 **Future tech Floating colonies on Venus**

40 **Have we found the edge of the universe?**

Whether our cosmos comes to an end is a question astronomers are tackling with some surprising results

48 **Mission profile ExoMars Trace Gas Orbiter**

52 **Astronomical impact of COVID-19**

The coronavirus has had seismic effects on all aspects of life, but what has the space industry been able to tell us, and what can it do to help?

60 **Crew Dragon launch**

This spring astronauts will return to Earth after their pioneering mission aboard the SpaceX capsule

64 **Ask Space**

Your questions answered by our space experts

RISE OF THE SUPER TELESCOPE



14

EARTH'S LAST DAYS



30

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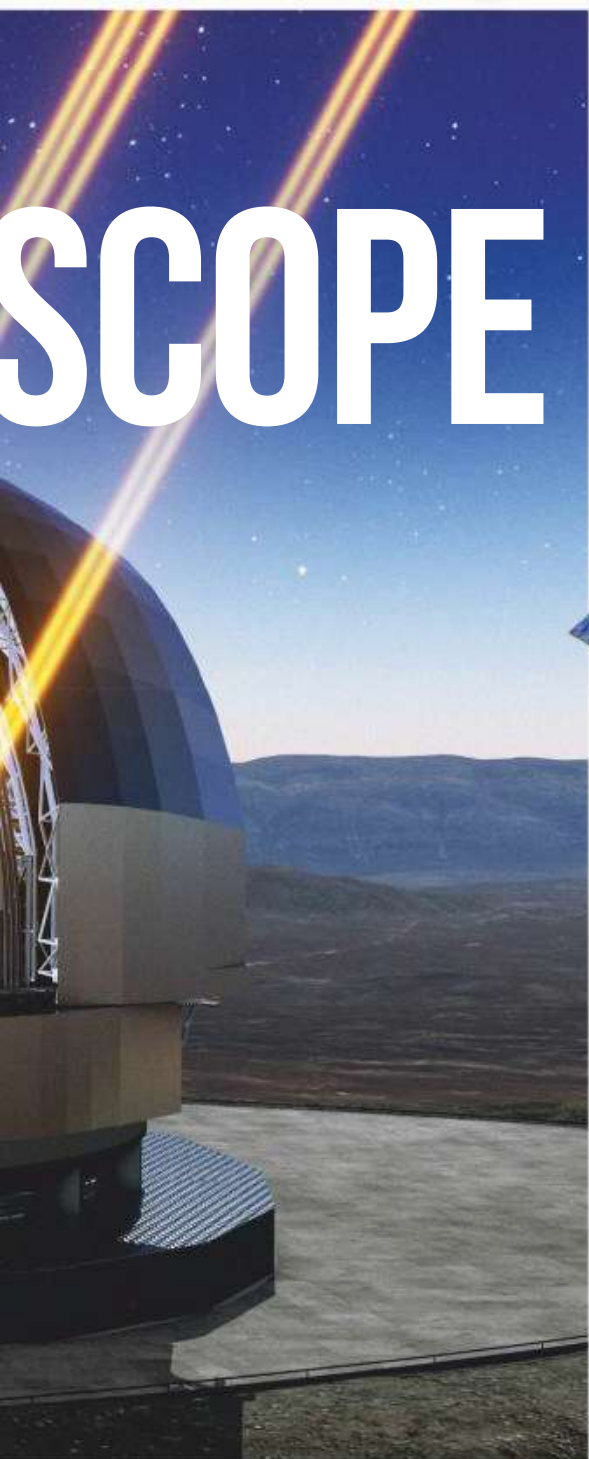
TURN TO **PAGE 62** FOR DETAILS



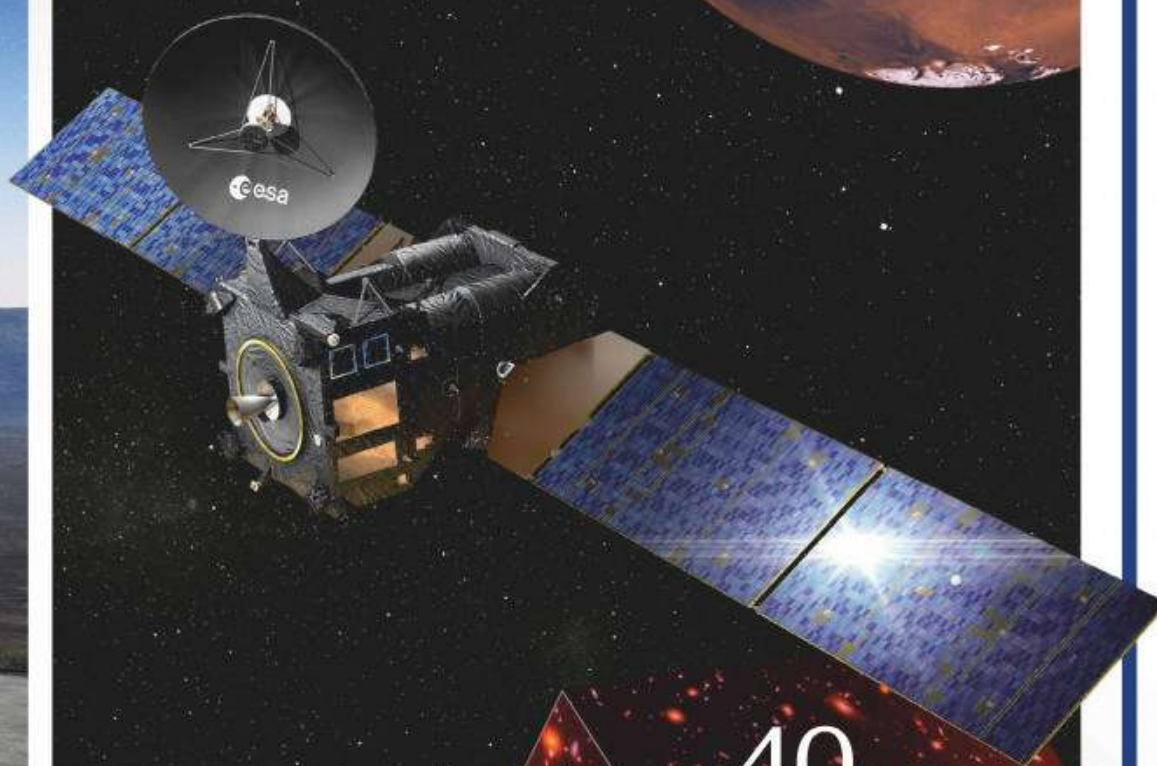


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59 Keep yourself occupied with space facts, the best of space.com and puzzles to test your problem-solving skills



MISSION PROFILE EXOMARS TRACE GAS ORBITER



48

40 EDGE OF THE UNIVERSE



52 COVID-19'S IMPACT ON EARTH

STARGAZER

Your complete guide to the night sky

68 What's in the sky?

You might have to stay up a little later, but the heavens are full of fantastic features

72 Month's planets

Jupiter is not only the king of the Solar System, but the ruler of the dawn sky

74 Moon tour

Find one of the most famous craters on the lunar surface: a science-fiction star

75 Naked eye and binocular targets

Use the tail of the Big Dipper as your guide

76 Deep sky challenge

June nights are perfect for exploring the hidden treasures of Ursa Major

78 The Northern Hemisphere

Late-night astronomers are treated to a stunning selection

80 Telescope review

Is the Celestron CPC 800 GPS (XLT) the right telescope for you? Here's our lowdown

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15

Hubble's 30th birthday photo

To celebrate three decades of top-class cosmic observations, the NASA/ESA's Hubble Space Telescope has once again delivered with a spectacular sight of the universe: the energetic bursts of star formation within the Milky Way's neighbouring dwarf galaxy, the Large Magellanic Cloud.

The larger magnificent centrepiece of this snap is known as NGC 2014 and is lit up by young stars ionising the hydrogen in the surrounding gas, giving it an orange-red hue.

The nebula's smaller companion is NGC 2020, coloured blue due to energised oxygen atoms. It's not too difficult to see why the pairing has been given the nickname of the 'Cosmic Reef'.



Painting or photograph?

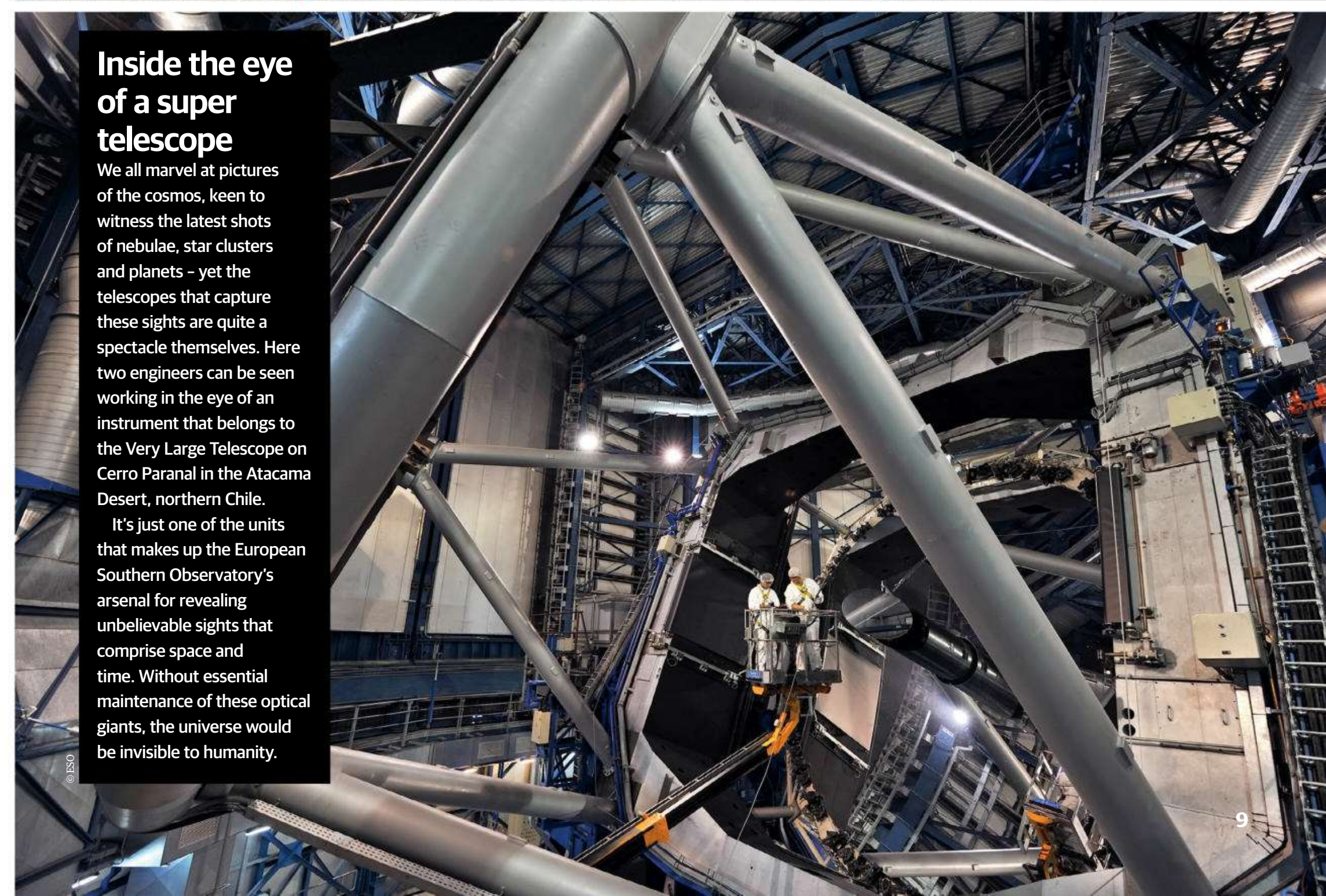
The vibrant blend and flow of colours on display could fool anyone into thinking this was the work of a talented artist. However, this particular painter is robotic: capturing its images from above, the Landsat 8 satellite snapped a picture of the Gulf Stream in the infrared wavelength. This stream stretches from Florida to Europe and plays an important role as a global ocean conveyor belt, transferring water and heat across the world between the continents separated by the Atlantic Ocean.



The galaxy that's a stellar lightweight

NASA/ESA's Hubble Space Telescope is a fantastic tool for seeking unusual targets in the universe - namely the elliptical dwarf galaxy designated PGC 29388. This small structure has exhausted all of the gas and dust needed for generating new stars, so exhibits no spiral arms - which is why it is referred to as 'elliptical'. Compared to our very own galaxy, the Milky Way, PGC 29388 contains a relatively minute amount of stars of only 100 million. Meanwhile, our home spiral boasts over 250 billion stellar members.

© NASA/ESA & Hubble



Inside the eye of a super telescope

We all marvel at pictures of the cosmos, keen to witness the latest shots of nebulae, star clusters and planets - yet the telescopes that capture these sights are quite a spectacle themselves. Here two engineers can be seen working in the eye of an instrument that belongs to the Very Large Telescope on Cerro Paranal in the Atacama Desert, northern Chile.

It's just one of the units that makes up the European Southern Observatory's arsenal for revealing unbelievable sights that comprise space and time. Without essential maintenance of these optical giants, the universe would be invisible to humanity.

© ESO

Borisov is the second known interstellar visitor to our Solar System

Strange ingredient in interstellar comet Borisov offers a clue to its origins

Words by Chelsea Gohd

Astronomers have revealed the unusual chemical composition inside 2I/Borisov, the interstellar comet that visited our Solar System last year. A strange ingredient has provided new clues about where this travelling space rock originated from.

2I/Borisov was discovered on 30 August 2019 by amateur astronomer Gennady Borisov. Following the appearance of interstellar object 'Oumuamua in 2017, this was the second object from another solar system ever discovered wandering through our cosmic neighbourhood. In December 2019 astronomers took a closer look at 2I/Borisov using the Atacama Large Millimeter/submillimeter Array (ALMA), a giant radio telescope in Chile.

In the new study an international team of researchers, led by planetary scientists Martin Cordiner and Stefanie Milam from NASA's Goddard Space Flight Center, analysed 2I/Borisov's chemical

make-up. The researchers found that the gas coming from the comet contained more carbon monoxide (CO) than has been detected in any other comet this close to the Sun - less than 300 million kilometres (186 million miles). In fact, the concentration of CO in the gas coming from this comet was between 9 and 26 times higher than in the average comet in our Solar System, according to a statement from the National Radio Astronomy Observatory (NRAO) which oversees ALMA.

Using ALMA, the team detected both CO and hydrogen cyanide (HCN). However, they found a similar amount of HCN in 2I/Borisov that's found in other comets in our Solar System, so that discovery wasn't much of a surprise. But the unexpectedly high quantities of CO offered a major clue as to where this comet came from.

"The comet must have formed from material very rich in CO ice, which is only present at the lowest

temperatures found in space, below minus 250 degrees Celsius (minus 420 degrees Fahrenheit)," said Milam.

"If the gases we observed reflect the composition of 2I/Borisov's birthplace, then it shows that it may have formed in a different way than our own Solar System comets in an extremely cold, outer region of a distant planetary system," said Cordiner.

Astronomers do not yet know what kind of star 2I/Borisov formed around, but these researchers suspect that 2I/Borisov came from a cold region in a larger protoplanetary disc, a rotating disc of dust and gas around a young star from which planets and planetary objects form. "Many of these discs extend well beyond the region where our own comets are believed to have formed, and contain large amounts of extremely cold gas and dust. It is possible that 2I/Borisov came from one of these larger discs," explained Cordiner.

Solved: mystery of Venusian atmosphere's weird rotation

Words by Charles Q. Choi

The mystery behind why the atmosphere of Venus spins much faster than the planet's surface may finally be solved. The finding might help shed light on how habitable distant exoplanets, worlds beyond our Solar System, may actually be.

Compared to Earth's 24-hour spin, Venus twirls at a leisurely pace on its axis, with its surface taking 243 Earth days to complete one rotation. However, the hot, deadly carbon-dioxide atmosphere of Venus spins nearly 60-times faster than its surface, whirling around the planet once every 96 hours in an effect known as super-rotation.

Previous research suggests that in order for this super-rotation to occur the atmosphere of Venus has to possess enough angular momentum - the amount of momentum a body has because of its spin - to overcome friction with the planet's surface. However, it was uncertain what exactly the source of this angular momentum was.

To shed light on this mystery, scientists from Hokkaido University in Sapporo analysed data from the Japanese space probe Akatsuki, which has orbited Venus since 2015. They focused on super-

rotation in the cloud layer of Venus, where the rotation speed is highest, reaching about 395 kilometres (245 miles) per hour in the region surrounding the equator.

Based on ultraviolet images and thermal infrared data from Akatsuki, the scientists developed a way to track Venusian cloud motions in order to map the planet's winds and the way heat circulated in the atmosphere. This helped to give the researchers a picture of how angular momentum was distributed across the cloud-top level, located at about 70 kilometres (42 miles) in altitude. This in turn helped them estimate the forces sustaining the super-rotating atmosphere.

The scientists discovered that the Venusian atmosphere received angular momentum through thermal tides, which are variations in atmospheric pressure driven by solar heating near the planet's equator. They also found planetary-scale waves in the atmosphere - as well as large-scale atmospheric turbulence - worked against this effect from thermal tides.



©ISAS/JAXA

Our Solar System stole asteroids from interstellar space

Words by Meghan Bartels

A cache of interstellar asteroids may have been hiding under scientists' noses for billions of years according to new research focused on a handful of strange space rocks known as Centaurs, which orbit the Sun in the neighbourhood of Jupiter and Saturn.

Centaurs' orbits are very unpredictable, with simulations suggesting that they should bang into things or fly out of the Solar System. The new research suggests that's because they were stolen by our Solar System when it was very young. With so much less expansion under the universe's belt, stars were closer. "The close proximity of the stars meant that they felt each others' gravity much more strongly in those early days than they do today," said Fathi Namouni, an astronomer at Observatoire de la Côte d'Azur in France. "This enabled asteroids to be pulled from one star system to another."

The new research focused on 21 objects in the outer Solar System: mostly Centaurs and a few other strange space rocks. Using a computer program, the scientists virtually cloned these objects tens of thousands of times over to understand likely scenarios for their escapades.

The analysis suggests that the Centaurs' strange-but-steady orbits are a hint they were born beyond

our Solar System and trapped here. Scientists have long hypothesised that objects move between solar systems, seeing the first confirmed interlopers in our neighbourhood in the past few years with 'Oumuamua and Comet Borisov.

Both of those objects only passed through our Solar System and weren't caught by the Sun's gravity. Scientists think early asteroids may have been more likely to wander into other star systems and get stuck because in the early days of the Solar System, with more than 4 billion years less of expansion, things were closer together.



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Apollo data creates best geological Moon map yet

Words by Chelsea Gohd

A new map has provided the blueprints for the Moon, revealing the true nature of Earth's rocky companion.

Scientists at the United States Geological Survey (USGS), in collaboration with NASA and the Lunar Planetary Institute, have created a comprehensive geological map of the Moon. In this new digital map the entire lunar surface has been thoroughly charted and all of its features classified, detailing exactly what makes up the beautiful variety of dark and light spots on the surface. It could also be invaluable for future crewed missions to the Moon.

"People have always been fascinated by the Moon and when we might return," said Jim Reilly, a former NASA astronaut and current director of the USGS. "It's wonderful to see USGS create a resource that can help NASA with planning for future missions."

The new digital map is so comprehensive because it uses data spanning the last five decades. The team behind the map used data from recent satellite missions to the lunar surface, as well as data collected and maps created during NASA's Apollo missions to and around our natural satellite.

Above: The white dwarf is being slowly stripped away from orbit

Black hole keeps snacking on white dwarf locked in its orbit

Words by Meghan Bartels

An astronomer thinks he's spotted a stellar corpse - known as a white dwarf - sending out blazes of light: mayday signals from its uncomfortably close orbit of a black hole. And while such a white dwarf is usually the result of a star naturally running out of fuel and exploding, it's thought the black hole itself snatched all of a red giant's free gas away, triggering the premature death. Such is the peril of treading too close to a black hole, even if it can't gobble you up.

"In my interpretation of the X-ray data, the white dwarf survived, but it did not escape," Andrew King, an astrophysicist at the University of Leicester in the UK, explained. "It is now caught in an elliptical orbit around the black hole, making one trip around about once every nine hours."

King's new research is based on observations gathered by NASA's Chandra X-ray Observatory and the European Space Agency's XMM-Newton X-ray

telescope. The pair focused on drama unfolding in a galaxy called GSN 069, located about 250 million light years away from Earth.

Every nine hours or so the galaxy experiences a spike in X-ray emissions. By analysing those spikes, King came up with his theory of a so-called near-miss tidal disruption event. Scientists have studied plenty of tidal disruption events, in which a black hole tears apart a star that comes too close.

When a wayward red giant first snuck too close, the black hole snatched away all its hydrogen, leaving just the core white dwarf behind. But the black hole, which contains about 400,000 times the mass of the Sun - a bit puny for a supermassive black hole - couldn't finish the job. Instead it trapped the white dwarf in a nine-hour dramatically elongated orbit, and at the closest point of each loop the black hole again sucks up a bit more of the star's matter, munching away at its meal.

Hubble image shows remains of ATLAS

Words by Meghan Bartels

Sky-watchers had high hopes that a comet called ATLAS would light up the night sky this spring, with forecasts suggesting it could become bright enough to see with the unaided eye. Instead the icy object crumbled to pieces - but it's still putting on a spectacular show for scientists. Ye Quanzhi, an astronomer at the University of Maryland, snagged some time with NASA's Hubble Space Telescope to

take a look at Comet ATLAS on 20 April and caught a stunning image of its fragments that he shared on Twitter as a preview of his research.

"We have been following the break-up of ATLAS since it was first detected in early April, but with ground-based telescopes we couldn't resolve most of the debris field," Ye said, adding that he was excited to see the new images. "With Hubble we are finally able to resolve individual mini-comets."

Ye hopes those mini-comets will help scientists understand what caused ATLAS to fall apart. In particular, astronomers rely on the distance between fragments to reconstruct events, since that distance increases as more time passes since a specific fracture.

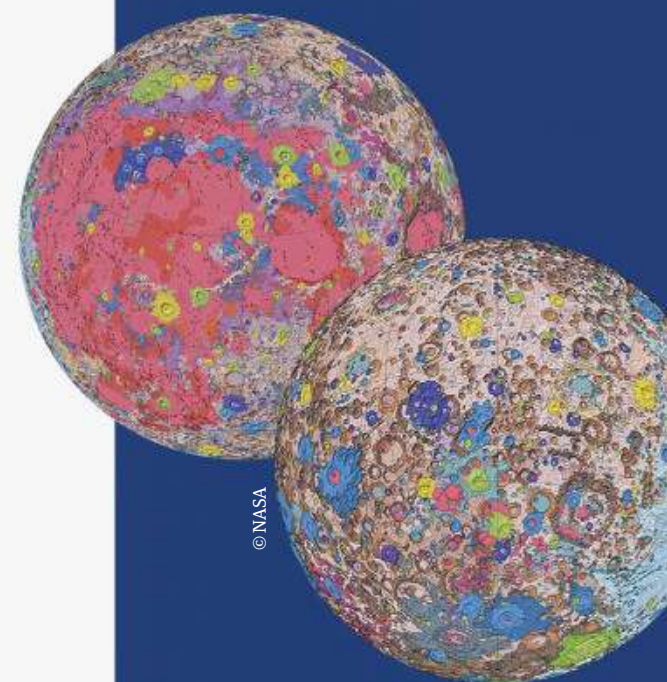
Previous observations had identified four main fragments from Comet ATLAS. In the Hubble image, Ye believes two of those pieces have broken down even more, yielding the two pairs of bright spots on the right, which represent the four largest fragments at the time.

Left: ATLAS was discovered at the end of December

Right: The map could be used for future NASA mission planning



Source: Wikipedia Commons © Martin Gernbecc



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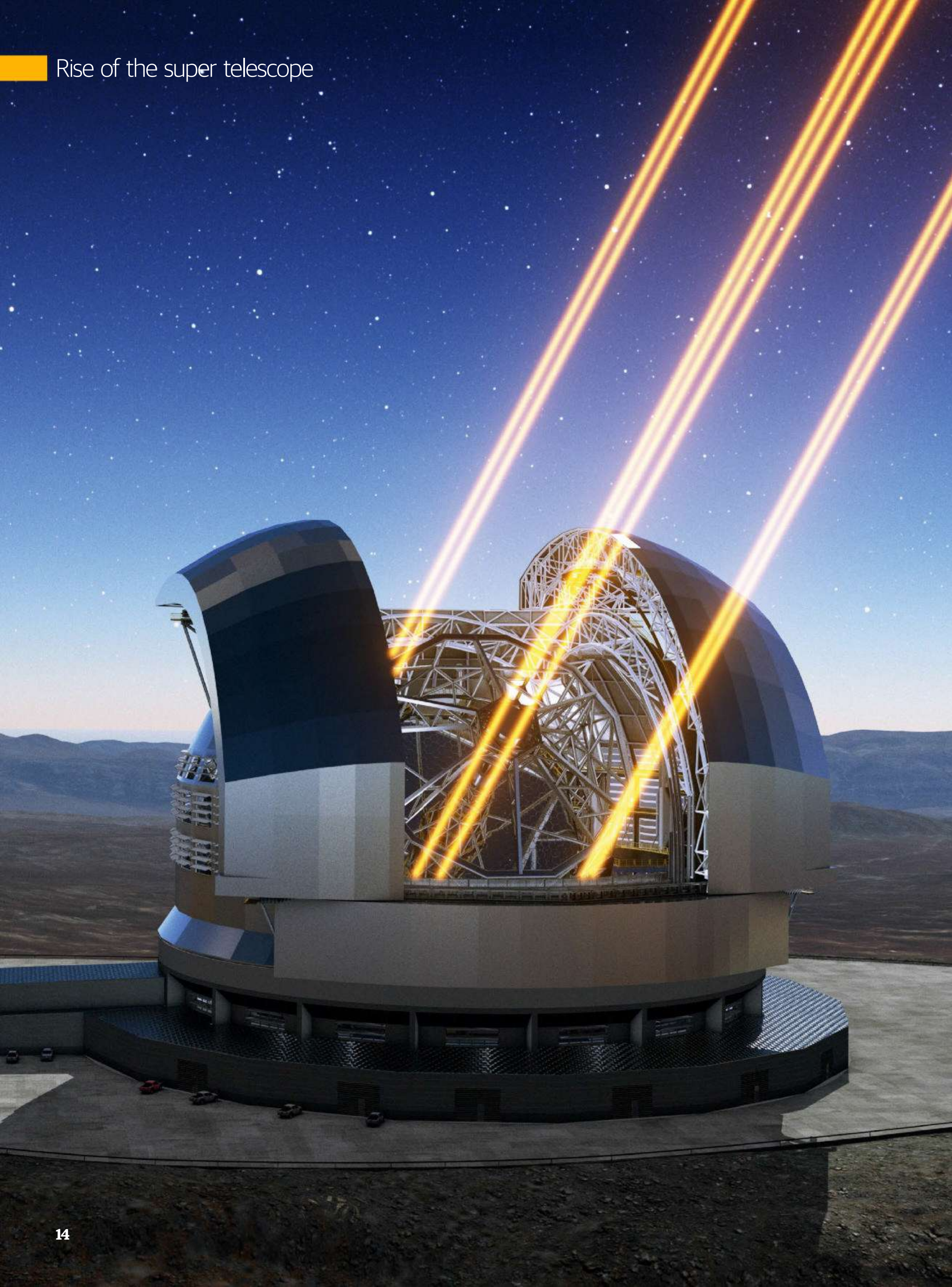
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RISE OF THE SUPER TELESCOPE

As work continues on its design and construction, we take you inside the Extremely Large Telescope as it prepares for first light

Reported by Dominic Reseigh-Lincoln



Who's involved in the ELT?

United Kingdom

The University of Oxford and the UK Astronomy Technology Centre are contributing to the HARMONI spectrograph.

France

France is involved in the design of the HARMONI, MAORY and METIS instruments.

Spain

Spain has made a number of contributions to the ELT, including the HARMONI spectrograph.

Italy

The Istituto Nazionale di Astrofisica is involved in the creation of the MAORY and MICADO instruments.

Germany

Germany's contributions to the ELT include the MICADO and METIS instruments.

The Netherlands

Nederlandse Onderzoekschool Voor Astronomie has been involved in the creation of the METIS and MICADO elements of the ground-based telescope.

Belgium

Belgium's Katholieke Universiteit Leuven has been working on the METIS spectrograph instrument.

Switzerland

ETH Zürich has worked on the ELT's METIS instrument.

Austria

The ELT's MICADO and METIS instruments have seen involvement from the Austrian Universität Wien.

European Southern Observatory Council

Work has also come from other members of the European Southern Observatory, including Portugal and Finland.

Looking further and deeper than ever before... that's the central goal that's driven astronomy since its inception. Studying the night sky and the universe that frames our world in ever-increasing detail, dissecting the light that's reaching our little world and discerning the grand legacy of the cosmos. For centuries humans have been building more and more powerful terrestrial telescopes that can see further into the void of space, each one expanding in size and breadth of vision.

That ever-increasing scale and desire to know more has brought us to the Extremely Large Telescope (ELT). A global initiative centralised by the European Southern Observatory (ESO) Council, the ELT project aims to construct the largest optical to near-infrared Earth-based telescope ever created with the intention of studying the furthest reaches of the universe, for the first time studying the properties and physics of the first galaxies and the behaviours of distant planets that orbit other stars.

The genesis of the project took place back in 2000, when European astronomers and scientists began discussing the desire to see the furthest reaches of the universe in more detail. Some of the largest telescopes in operation at the time, such as the Gran Telescopio Canarias - based in the Canary Islands - or the Very Large Telescope (VLT) - based in Chile just 20 kilometres (12.4 miles) from the future ELT site - were capable of identifying these far-flung points in space, but were too primitive to study them in depth.

Below: Almost a million tonnes of rock was blasted off the top of Cerro Armazones, reducing its height by around 40 metres (131.2 feet)

So began a planning and preproduction stage that lasted over ten years as the ESO Council began calculating how much and how long it would take to build the ELT. Over this period, each of the 15 - 16 following the admittance of Brazil in 2010, though the nation is awaiting ratification of the Accession Agreement - member states of the ESO Council began drawing up Phase 1 plans, which presented research and development plans in order to secure different contracts for each element of the ELT. In 2018 the cost of telescope was around £1 billion (\$1.3 billion) with a planned 'first light' set for 2025.

For Simon Morris, a professor of physics at the University of Durham; a member of the team working on the ELT's Multi-Object Spectrograph for Astrophysics, Intergalactic-medium studies and Cosmology (MOSAIC) instrument and the UK astronomy representative for the ESO Council, studying those distant glimpses of the first galaxies is exactly why something as grand as the ELT is needed. "I've always done research on how galaxies form, and I feel that's the most interesting thing we'll be able to do with the ELT. The galaxies that we can see at the furthest distance are showing us the point where the universe went from being neutral to being ionised, so the things that formed in this period essentially cooked the universe," he says. "We can see some galaxies at the point when that happened, but it's very difficult to study them in great detail. The current class of telescopes can only just barely detect them, and can barely perform spectroscopy. With the ELT we will finally



Building a towering telescope

From its giant mirrors to its state-of-the-art instruments, the ELT is set to be a marvel of modern engineering

1 Primary mirror

The 39.3-metre (128.9-foot) primary mirror is made up of individual hexagonal segments and collects light from the sky. It reflects all of that light back towards the secondary mirror.

2 Secondary mirror

At 4.2 metres (13.8 feet), the secondary mirror is designed to support the light-gathering power of the main mirror. It will reflect light towards the third mirror in the process.

4 Fourth mirror

This special adaptive mirror is designed to shake a thousand times a second. It does this in order to correct the images collected for atmospheric distortions that cause blurring.

5 Fifth mirror

The fifth and final mirror in the five-mirror sequence - which is also moving at a fast speed - receives the now-corrected light from the previous four components and sends it to the cameras and instruments.

6 Laser guide stars

In order to light up parts of the sky that may be too dark to study in their natural state, the ELT will have an in-built laser guide system to help pinpoint and illuminate areas of observation.

7 Rotating platform

To study the night sky from on top of Cerro Armazones, the 2,800-tonne telescope can rotate a full 360 degrees. This gives the ELT an unprecedented all-round view of the cosmos.

9 HARMONI

The High Angular Resolution Monolithic Optical and Near-infrared Integral field spectrograph is another of the ELT's first-light instruments. It will enable scientists to measure the spectra of light around planets and stars.

10 Seismic isolators

Northern Chile may have exceptionally clear night skies, but it's susceptible to powerful earthquakes. To help counteract this, the ELT has an isolation platform to absorb the shocks.

3 Third mirror

The third mirror in the five-mirror ELT set-up collects the light bounced from the primary and secondary mirrors and delivers it towards an adaptive flat mirror positioned above it.

8 MICADO

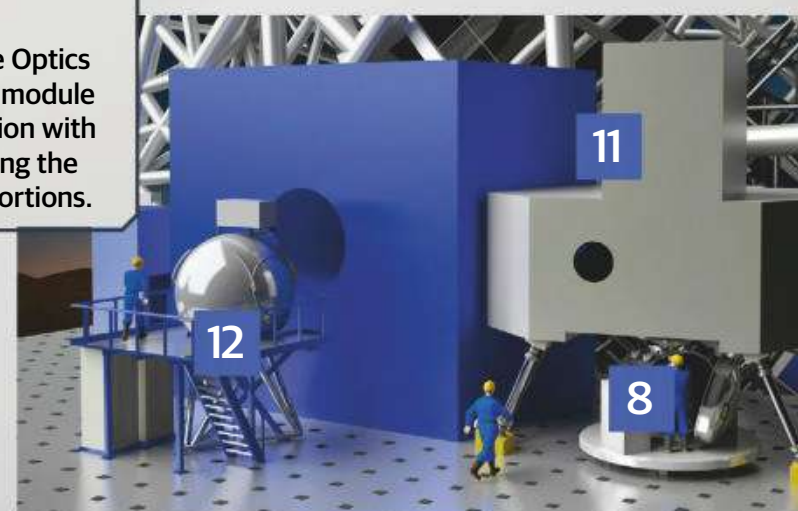
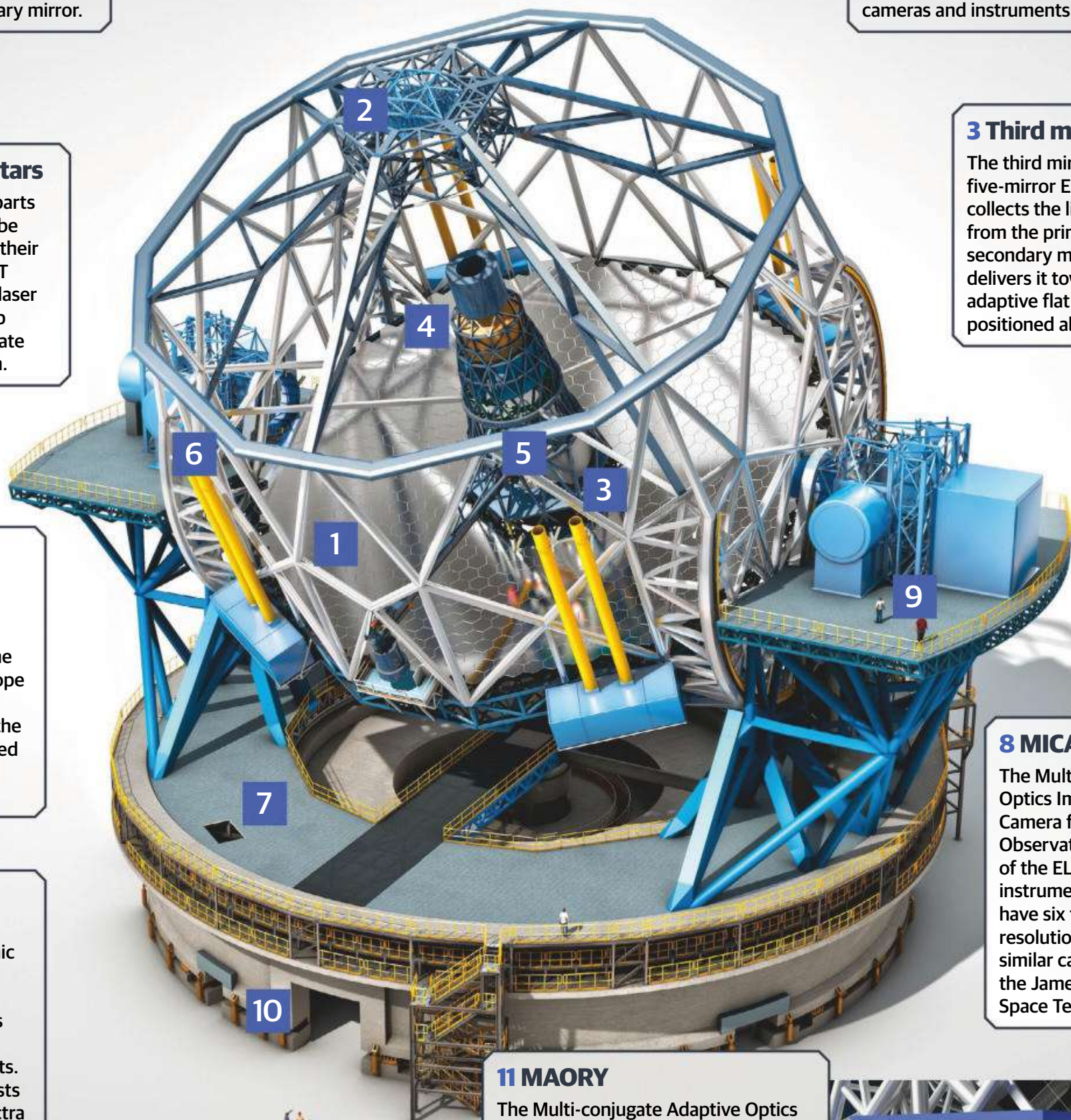
The Multi-Adaptive Optics Imaging Camera for Deep Observations is one of the ELT's first-light instruments and will have six times the resolution of the similar camera on the James Webb Space Telescope.

11 MAORY

The Multi-conjugate Adaptive Optics RelaY instrument is an optics module designed to work in conjunction with the adaptive mirrors, correcting the light captured to remove distortions.

12 METIS

The Mid-infrared ELT Imager and Spectrograph will be the third instrument and will enable scientists to study the chemical properties of exoplanets and stars.



Rise of the super telescope

be able to study the distant cosmos with a new sense of clarity."

The ELT will have the potential to provide data for the entire astronomical community, performing hundreds of tasks with six currently planned instruments. As a telescope with the power to see light from around 1 billion years after the Big Bang, the ELT will focus its attention on the first galaxies of the universe and how they evolved and transformed across the cosmic timeline. We'll have the ability to study the ancient elements at their heart - primordial stars, planets and black holes that helped shape the space around them.

We'll also have the opportunity to study another fact of astronomy that continues to fascinate scientists: planets that orbit stars outside our own system, or exoplanets. In the eternal search for planets that share the characteristics of Earth - and by proxy the potential to support life as we know it - the ELT will be able to study these distant planets as they orbit far-flung stars, discerning their composition and the nature of their suns.

But how big does a telescope have to be to capture these distant times, and do so with an almost unheard of clarity? The ELT will have a huge 39.3-metre (128.9-foot) wide primary mirror, with a 4.2-metre (13.8-foot) wide secondary mirror, a third supporting mirror 3.75 metres (12.3 feet) in diameter and two additional mirrors that can be adjusted to remove atmospheric blurring. It will be able to

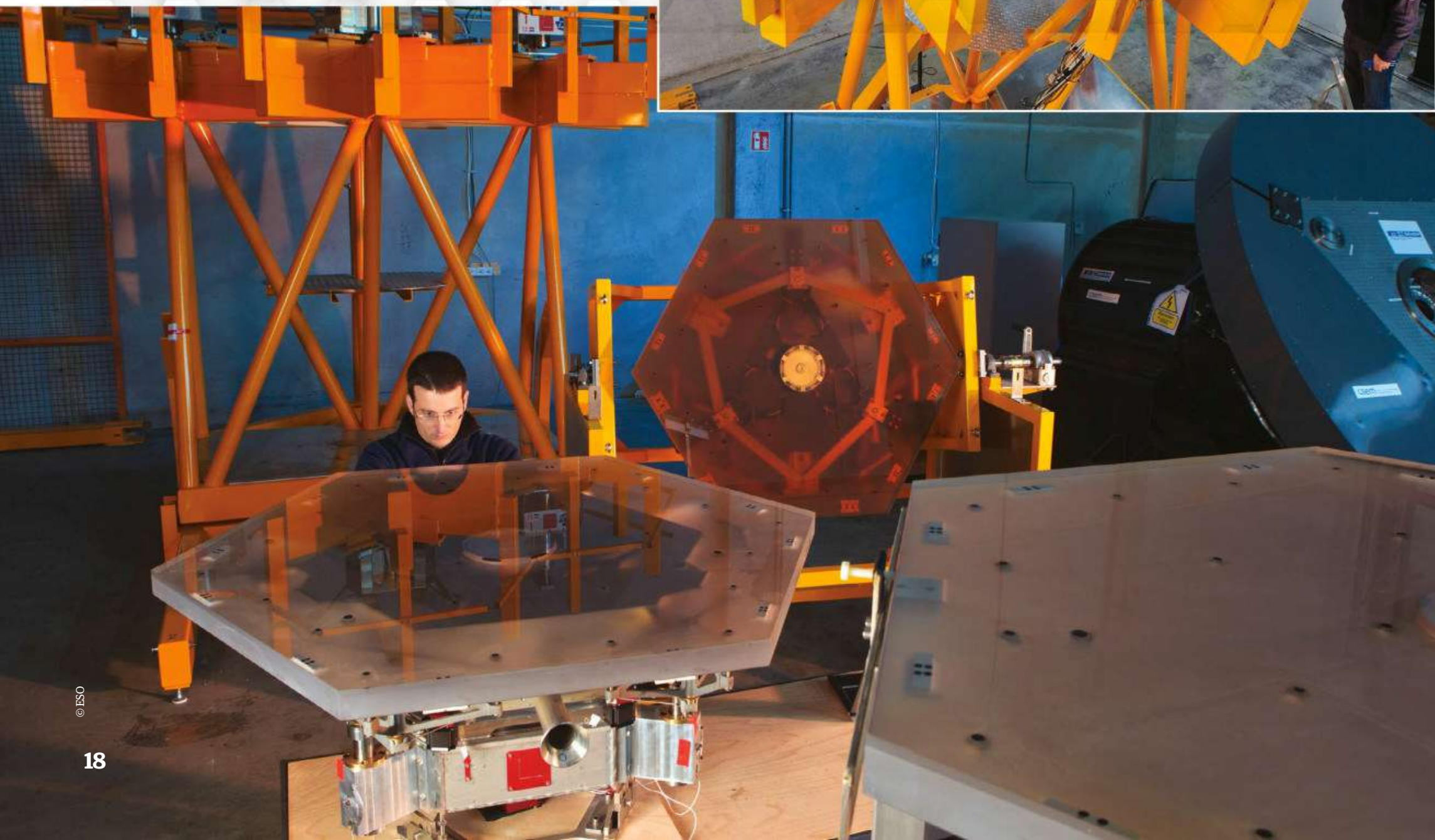
gather more light than all the eight to ten metre (26.2 to 32.8 foot) telescopes on Earth combined - to put that into perspective, the ELT will be able to capture 100 million times more light than the human eye and detect objects millions upon millions times fainter than that.

"The ELT will be able to study objects that are much fainter with just as much depth as far brighter celestial objects," says Niranjan Thatte, a professor of astrophysics at the University of Oxford and project leader on the High Angular Resolution Monolithic Optical and Near-infrared Integral field spectrograph (HARMONI). "Fainter doesn't always mean further away - for instance, planets are usually fainter in comparison to stars - but in most cases reduced light almost always means it's at a considerable distance. Since the light has taken a long time to get

to us, we need a telescope that has the potential to study light originating around 1 billion years after the Big Bang. Being able to study these galaxies in their youth, we can learn when a galaxy's given stars were created or what the properties of these infantile areas of space were in this formative cosmic period."

Originally envisioned with a 100-metre (328-foot) diameter mirror - though this idea was eventually scrapped as it was both unfeasible and far too costly to construct - the ELT will be built on a specially chosen location in northern Chile. The site itself, a mountain known as Cerro Armazones, was chosen for its high rate of clear skies, making it an ideal location for gazing into the stars.

The mountain itself has already been prepared for the first stage of the telescope's on-site



"WITH THE ELT WE WILL FINALLY BE ABLE TO STUDY THE DISTANT COSMOS WITH A NEW SENSE OF CLARITY"

SIMON MORRIS

construction, with a controlled explosion in June 2014 blowing millions of rocks from its peak. The controlled demolition reduced the mountain by 40 metres (131.2 foot) and will see the ELT sitting at a final altitude of about 3,046 metres (9,993 feet).

The main mirror of the telescope, which was downgraded from the original 100-metre (328-foot) design envisioned for the first version of the ELT, was adjusted in 2005 in order to keep the whole project within the original budget. The question is, however, how much of an effect will these seemingly minor adjustments have on the wider capabilities of the finished project? "The reduction in size for the primary mirror from 42 metres (138 feet) to 39.3 metres (129 feet) reduces both the sensitivity of the telescope and the angular resolution - the detail that can be observed in the sky," explains Colin Cunningham, director of the E-ELT UK Project Office.

"The angular resolution reduces linearly with the diameter of the primary mirror, so the reduction did not have a huge impact on the detail we will see. However, the reduction in mirror area makes a big difference to the sensitivity by reducing the number of photons collected. For some science the reduction in sensitivity goes with the fourth power of mirror diameter or more. This means that it will be more difficult to directly observe exoplanets, for example. However, the ELT will still be much more sensitive than its nearest rival, the US-led Thirty Meter Telescope," Cunningham adds.

Even with that slight reduction in size, the primary mirror still forms part of a unique five-mirror set-up that will prove vital in enabling astronomers to study the earliest light in the universe with an untold clarity. Those extra mirrors will enable astronomers to look through incredibly fine angular scales across a large angle of the sky.

"In this case it means that we can study the sky to a scale of ten arcminutes - a unit of angular measurement equal to 160th of one degree - and for a 39.3-metre (129-foot) diameter telescope, that's an incredible field of view," reveals Morris. "Apart from blurring from the atmosphere, the images will be measured in micro-arcseconds [millions of a 60th of a 60th of a degree], so incredibly tiny angles will be detectable."

There's also the introduction of an already established astronomical technology known as 'adaptive optics'. Looking so far into the cosmos leaves such a gaze open to 'atmospheric turbulence', the natural phenomena caused by the atmosphere

Right: The large diameter of its primary mirror will enable the ELT to study both distant galaxies and exoplanets

Top: Four segments of the primary mirror are placed on supports and tested to see how they behave together when tilted to 45 degrees

Left: Several segments of the ELT's huge primary mirror being tested in Germany



Rise of the super telescope

of our world partially obscuring stars and causing them to twinkle. This disturbance causes blurring to a telescopic eye, so a countermeasure is required to remove it.

One of the mirrors in the ELT will be deformable, so it can actively change its shape around a thousand times per second. In order to pull this off the mirror needs additional ones to work on this scale, hence the decision to have a total of five in effect. Another one of these five mirrors will tip and tilt on a similar timescale and compensate for this blurring. On top of this the ELT will use a laser guide system that will project beams of light towards the chosen point of observation - since not

every point of study will have a suitable star present to generate enough light, these 'artificial stars' will provide the perfect conditions for study.

"The five-mirror design enables a huge, deformable mirror - which is 2.5 metres (8.2 feet) in diameter - to be incorporated," comments Cunningham. "This is controlled by over 5,000 actuators to compensate for atmospheric distortions and wind shake to ensure that the telescope images are the best possible. The other key technologies include the active support structure for the 798 hexagonal mirrors forming the 39.3-metre (129-foot) wide primary mirror and the laser guide system that will enable adaptive optics to be carried out

anywhere in the sky, not just near to bright 'natural' guide stars."

The ELT won't just have a unique mirror system, but also a large selection of precise instruments for studying the properties and physics of the wider universe. The ELT needs to be able to support the wider astronomical community, so a series of tools have been placed into an order of importance that will see each one systematically added to the observatory over time as it becomes more and more capable. For instance, the UK is part of two vitally important instruments for the ELT: the aforementioned MOSAIC multi-object spectrometer and the HARMONI visible/near-infrared

The biggest eye on the sky

Based in the Chilean Atacama Desert, the ELT will be the largest and most impressive telescope ever constructed by humans

Creating the world's largest telescope is no mean feat - it is one that requires a viable site as well as primary and secondary mirrors big enough to see further into space than we've ever seen from an Earthly lens. That's why the ELT has been a global initiative, with a huge roster of countries providing materials, research and consultation on its design and construction.

Since the ELT will form part of the European Southern Observatory network, a site in Chile was chosen for the new super telescope. The ESO already has a considerable presence in the South American nation, so the chosen location of Cerro Armazones makes perfect sense - especially when you consider it's ideal nature for stargazing - it has 89 per cent cloudless nights a year.

The mirrors used will be some of the largest ever constructed for a terrestrial telescope, with a 39.3-metre (129-foot) primary mirror and the secondary one still an impressive 4.2 metres (13.8 feet) in diameter. The combination will gather 13-times more light than any other optical telescope on Earth, and will offer the ability to adjust for atmospheric distortions. Better yet, it will provide the opportunity to capture images 16-times sharper than the Hubble Space Telescope.

The London Eye

At 135 metres (443 feet), the Eye towers over the Extremely Large Telescope by a massive 61 metres (200 feet).

Arc de Triomphe, Paris

One of the most famous monuments in Paris, the Arc de Triomphe stands at 50 metres (164 feet) tall - shorter than the ELT.

ELT, Chile

The largest telescope ever constructed, the ELT exterior dome will reach 74 metres (243 feet). The dome has a diameter of about 86 metres (282 feet).

spectrometer. HARMONI will be one of the first two instruments added to the ELT, and will be there to ensure the telescope receives first light in 2025.

The MOSAIC multi-object spectrometer, which is being researched and designed in cooperation with astronomers and engineers in France and the Netherlands, is designed specifically for use on a telescope as big as the ELT. At its core a spectrograph is used to separate out and measure the wavelengths present in electromagnetic radiation - it determines the spectrum of light around and emitted by a given object in space. That same principle applies to MOSAIC, only this time the spectrograph needs to make multiple copies

of the same area of space in order to study the different elements.

"With the ELT we want to look at multiple objects spread across a considerably large field of view," says Morris, part of the UK team working on the MOSAIC component. "And we want to do that using adaptive optics, so there's the challenge there of making these two fields work in harmony. The UK has actually been taking a lead on these tests, known as multi-object adaptive optics, and we've actually been testing that in collaboration with a number of engineers from Paris to show that these principles will work when the ELT hits first light."

Alongside MOSAIC, the ELT will also house another significant piece of astronomical equipment: the HARMONI optical and near-infrared spectrograph. The contract to design and construct this instrument was awarded to the UK in September 2015 and will reportedly cost £50 million (\$62.2 million). The project is being led by a team of researchers at the University of Oxford. A near-infrared spectrograph is designed to measure the cool atmospheres of stars where new molecules form. By studying the rotational and vibrational nature of these molecules, astronomers can then gain a greater understanding of the nature of the star that bore them.

Statue of Liberty, New York

Lady Liberty measures 93 metres (305 feet) from the ground to her torch - roughly the same as a 22-storey building.

Great Pyramid of Giza

The ELT is dwarfed by the Great Pyramid, standing at an impressive 137 metres (450 feet).

Very Large Telescope, Chile

The Very Large Telescope at the Paranal Observatory is dwarfed by the ELT, barely scraping 30 metres (98 feet).

The Colosseum, Rome

The Colosseum remains fearsome, but at 48 metres (157.5 feet) it's just over half the height of the ELT.

Objectives of the ELT

From probing primordial galaxies to tracking exoplanets, the ELT has an ambitious series of scientific goals

Study the formation of stars in the first galaxies

The light-gathering capabilities of the ELT will enable us to study how the first galaxies were formed and how stars were born in this chaotic early stage in the universe's life. By seeing these points in space in their youth, we can see if all their stars were created at the very beginning or whether they already existed and were passive for long periods of time. This large telescope will help us to figure out if stars were born in bursts of activity every few billion years.

Observe what was previously impossible

"Every time mankind has been able to make a technological leap forward in what is achievable in terms of observations, we've found it's drastically improved our understanding of the cosmos," comments Thatte. "So, for us, it's the ability to look out into the furthest reaches of the stars and discover something new that we've never seen before. Those first galaxies could yield secrets about the primordial galaxies that we have never even considered."

Learn about exoplanets and their stars

"It is world-class. It will have a really broad application across almost every area of astronomy," comments Morris. "Just with our multi-object spectrograph you can perform hundreds of applications, including the search for extrasolar planets. We want to study the spectra of a star - from this we'll be able to observe a Doppler shift if it has a large enough planet orbiting it, so you'll see a shift in its velocity, relative to us, as it wobbles as the planet goes around it."

Study the accelerating expansion of the universe

"It will have multi-purposes and will make major advances in astronomy, from galaxy evolution in the early universe, through the study of black holes, to understanding how planets form outside of the Solar System," says Cunningham. "It will achieve this by a combination of increases in angular resolution by a factor of 15, compared to Hubble, and sensitivity of up to 500-times better than current telescopes."

Search for worlds that are like Earth

"The most exciting thing about not just detecting exoplanets in the universe, but also measuring their properties is that it may bring us much closer to understanding if Earth is unique in its planetary characteristics. Similar to observing the first galaxies, it is not just about detection here, but understanding the astrophysical properties of exoplanets," says Cunningham. Spectroscopy allows us to look at the atmospheres of planets and look for signatures that suggest life.



Right: If all goes to plan, the ELT will see its first light in 2025



"HARMONI will be a four-metre (13-foot) tall cryogenic instrument, which requires us to cool every element of the tool down to around -153 degrees Celsius (-243 degrees Fahrenheit)," comments Thatte. "We do this because any amount of heat produces radiation. Any kind of radiation, even the smallest amounts, can be detected by a near-infrared spectrograph, so unless we cool everything down to a significantly cold temperature, these pockets of radiation will distort the readings we'd be attempting to make."

Another challenge faced by the HARMONI spectrograph, and the ELT as a whole, is seismic activity found in the Chilean region selected for the telescope. The VLT, based at Cerro Paranal, has already experienced and endured a magnitude 8.0 earthquake - considered 'Great', the most severe band for seismic classification - so the ELT and its instruments will need to be reinforced in order to withstand these natural occurrences. "In that sense the ELT will have something in common with a space telescope," adds Thatte. "Just as a telescope will have to survive the launch process, so will our instruments have to withstand considerable destructive forces."

Alongside its six planned instruments, there's also the potential to build an imager powerful

enough to take pictures of identified exoplanets.

"There's currently a discussion to build something along those lines for the ELT," says Morris. "But the general consensus is that the technology needed to make it a reality isn't quite ready yet, so there's a rolling technology development going on now and teams are working on proving it can be done. If those results prove positive, then it will be included in the final telescope set-up."

The potential to study these distant worlds in greater detail remains one of the most incredible prospects for the ELT and has the potential to change the way we see the wider cosmos forever. With thousands of exoplanets having been detected across our galaxy by pioneering missions such as Kepler and the Transiting Exoplanet Survey Satellite (TESS), finding out more about these worlds is a hot topic in astronomy. "The most exciting thing about not just detecting and locating exoplanets in the

universe, but also measuring their properties is that it may bring us much closer to understanding if Earth is unique," muses Cunningham. "Again, with the first galaxies, it is not just about detection, but understanding their astrophysical properties using spectroscopy that will open up new understanding about how the early universe evolved."

With less than five years to go until the ELT's proposed first light detection sometime in 2025, the road to a fully operational Extremely Large Telescope is well underway. With 16 countries contributing to its inception, design and construction, it's set to become a truly world-class example of modern engineering. Through its many lenses astronomers will be able to see into the cosmos like never before, studying the properties of exoplanets, the formation of the first galaxies, the genesis of primordial systems and the expansion of the very universe itself.

"THE ELT'S HUGE LIGHT-GATHERING CAPABILITIES WILL ENABLE US TO STUDY HOW GALAXIES AND STARS WERE BORN" NIRANJAN THATTE

THERE'S MORE WATER ON JUPITER THAN FIRST THOUGHT

Observations from the Jovian king's companion spacecraft have turned up an astounding result

Reported by Elizabeth Howell

“HOW MUCH WATER JUPITER SOAKED UP SHOULD HELP SCIENTISTS EXPLAIN ITS FORMATION”

Newly released data from NASA's Juno probe shows that water may make up about 0.25 per cent of the molecules in the atmosphere over Jupiter's equator.

While that doesn't sound like much, the calculation is based on a prevalence of water's components, hydrogen and oxygen, three times more than at the Sun. The new measurements Juno obtained are much higher than a previous mission suggested.

The surprise result has scientists delving deep into results from NASA's Galileo mission to Jupiter, which obtained drier results in 1995 when engineers deliberately threw the spacecraft into Jupiter's atmosphere. Galileo was low on fuel and NASA didn't want to take the chance, even if it was a slight one, of the spacecraft accidentally crashing on a potentially habitable icy moon.

Reconciling the results from Galileo and Juno is key for scientists to better understand how our Solar System came together. Since Jupiter was probably the first planet to form, it could have sucked up most of the gas and dust that the Sun's formation left behind. How much water Jupiter soaked up should help scientists identify the most plausible theories to explain its formation.

And understanding Jupiter's birth would in turn help scientists understand how the planet's wind currents move and what its insides are made of. Scientists should also be able to generalise findings at Jupiter to certain kinds of large exoplanets to learn how other solar systems formed.

Galileo's results were a puzzle, even back in the 1990s. The spacecraft sent back data showing ten-times less water than scientists predicted and, more weirdly, the amount of water appeared to increase the deeper Galileo went into Jupiter's atmosphere. Scientists had expected that by the time it stopped transmitting data at a depth of about 120 kilometres (75 miles), the atmosphere around it should have been well mixed with an unchanging composition. A ground-based infrared telescope was able to measure water concentrations at Jupiter at the same time as Galileo's plunge and showed that Galileo may have hit a dry spot, meaning water is not well mixed deep in Jupiter's atmosphere.

Juno's first eight flybys also showed a lack of atmospheric mixing. Its radiometer obtained data even deeper than Galileo's measurements at 150 kilometres (93 miles) down, and found more water at the equator than Galileo did. Scientists are now waiting to compare Juno's equatorial measurements with observations at the north of the planet; Juno's 53-day orbit is gradually moving northward to examine more of that hemisphere with each flyby.

“Just when we think we have things figured out, Jupiter reminds us how much we still have to learn,” said Scott Bolton, Juno principal investigator at the Southwest Research Institute.

Left: With each new flyby Juno brings more to light about the gas giant

INTERVIEW BIO

Professor Lisa Harvey-Smith

Harvey-Smith is a British-Australian astrophysicist working as professor of practice in science communication at the University of New South Wales, Sydney. In 2018 she became Australia's first Women in STEM Ambassador.

She received her doctorate in radio astronomy from Jodrell Bank Observatory at the University of Manchester, UK, and then went to work at the Joint Institute for Very Long Baseline Interferometry European Research Infrastructure Consortium (JIVE) in the Netherlands. On moving to Australia, Harvey-Smith became project scientist of the Australian Square Kilometre Array Pathfinder (ASKAP). Harvey-Smith has also written two books about astronomy and astrophysics: *When Galaxies Collide* and children's book *Under the Stars: Astrophysics for Bedtime*.



THE WONDERS OF RADIO ASTRONOMY

Radio can unmask many hidden properties about the universe, including merging galaxies and Fast Radio Bursts. Professor Lisa Harvey-Smith speaks to **All About Space** about the mysterious majesty of the field

Reported by Lee Cavendish

What can be learnt from radio astronomy that isn't revealed in other spectrums of light?

Until about 400 years ago, we were, as human beings, completely blinkered. We didn't have telescopes. We just had our own eyes and we just had the eyes that have evolved over millions of years of animal evolution on planet Earth. For that reason we can only see a tiny, narrow part of the spectrum. It was only much more recently that we started taking off the blinkers, certainly in the early 20th century. We started to realise there were other types of light that we could gather. And one of those invisible colours is radio waves.

We started to use those radio waves, not just for communication, but to passively receive information from space. Radio waves let you see the invisible. And they also let you find out so many layers of colours that we can't see. For example, in the middle of our galaxy - the Milky Way - there's so much dense, dusty gas that is completely black. All of that is hidden from view until we use infrared radiation, or if we use radio waves, and that's what those different colours can teach us about how hot the gas is, about what it's made of, what chemicals are up there in space and also the types of physical conditions in the stars.

A lot of the scientific goals of ASKAP are centred around galaxies, whether it's their evolution, formation or population. What links them?

There are lots of forces in our universe. Some hold together the middle of atoms, like electromagnetism. They hold together all the sort of physical matter that we are made of, a table, a

chair, the planet. But gravity holds together things on these larger scales, so gravity is the master of the universe. It's quite a weak force but it's a pulling force. We live in a single galaxy called the Milky Way with 200 billion stars and tonnes and tonnes of gas. But we also live in a region with about 50 other galaxies, and they are our sort of galactic family, called the 'Local Group', and gravity glues all that together.

How important is the study of galaxies to understanding how the universe was born?

Galaxies are kind of the basic unit of the universe, if you like. There are smaller things. There are atoms, I would say, as an analogy of the universe. [Galaxies] are made of stars, just like atoms are made of electrons, protons and neutrons. There are smaller objects, but galaxies are kind of the fundamental

unit, and each galaxy tells us a different story. It's a snapshot of a very, very long life of billions of years. Most galaxies are 12 or 13 billion years old. Some are younger. But many of them have a very complicated life story. They started off with a particular colour, a particular shape and a particular size, and they've evolved through time. Many of them have collided, many of them have merged with other galaxies and many have had huge things smashed into them, completely transforming their colour, shape, mass and size. The fact that they're all rushing apart from each other due to expansion has taught us about the Big Bang and the fact that the universe started all in one place.

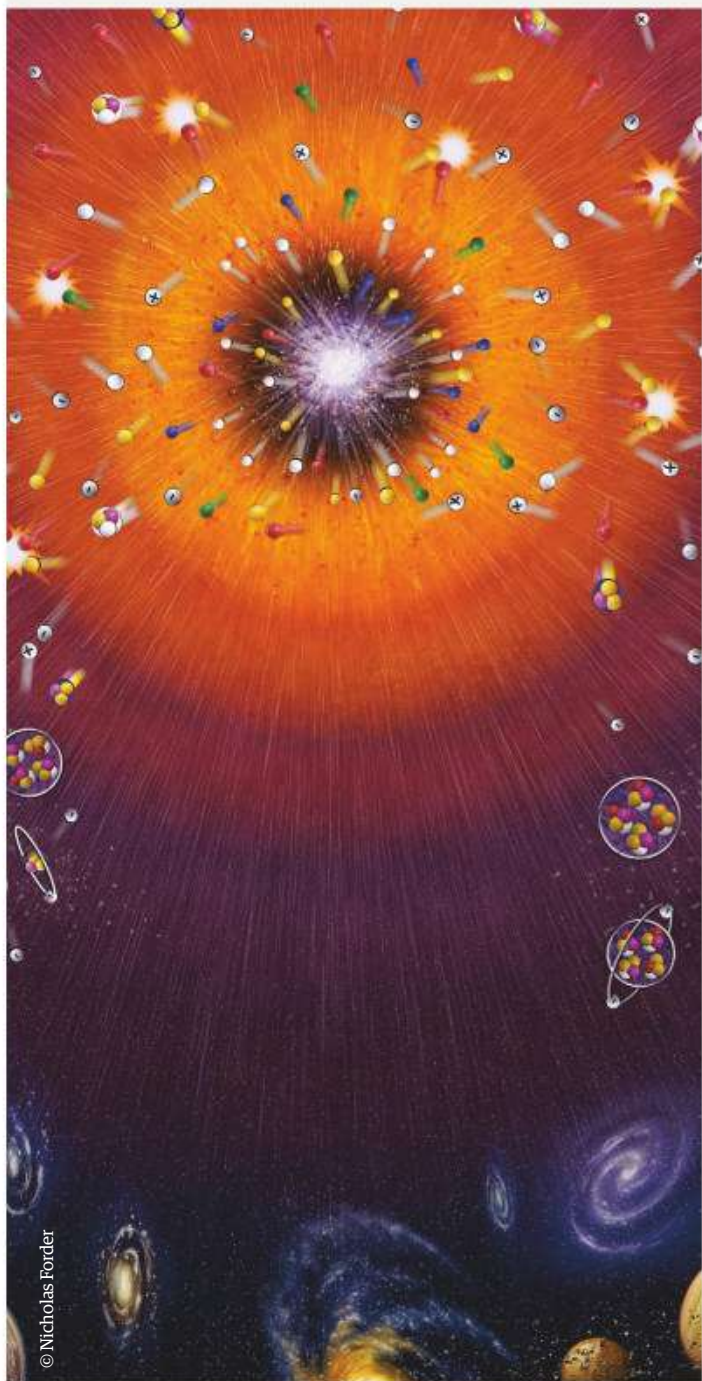
Do you see a correlation in galaxies' appearances as you look further back in time?

Yeah. Well, a lot of the galaxies started to appear

Right: Radio observations are key in identifying neutron star collisions, which consequently produce gravitational waves



Interview Professor Lisa Harvey-Smith



quite soon after the Big Bang. We don't know exactly how long. That will be the job for the new Square Kilometre Array (SKA) telescope to see when the very first stars and galaxies were born. But we think it's less than a billion years after the Big Bang, which isn't too long, given that we're nearly 14 billion years now on the clock.

You've talked about the eventual collision between the Milky Way and the Andromeda Galaxy. Assuming humanity is still alive on Earth at this point, what kind of effects would we experience from that kind of galactic collision?

This is absolutely fascinating. I could go on all day about it. I explained this in my book, *When Galaxies Collide*, but the Milky Way galaxy and the Andromeda Galaxy - the nearest spiral galaxy to us - are currently rushing together at 400,000 kilometres (250,000 miles) per second. And we should collide in about 3.8 billion years.

Now when two objects like two cars collide: smash! You get an immediate rebound. You get a lot of damage. But galaxies are mostly empty space - like space is full of space. The stars are very small, and there are billions of them, but there's a lot of gaps between them. When the two galaxies collide, they should actually just pass through each other like two ghosts.

There is other stuff in the galaxy though, like the gas that fills the spiral arms. Now that gas will - due to gravity - sort of stick together, and it will kind of crush the gas and cause that gas to

get very dense, or squashed. That can trigger star formation, so there will be a whole new generation of stars created, kind of like a firecracker of events. Suddenly there will be probably thousands, if not millions, of new bright stars, just like the brightest ones that we see in the sky, like Sirius and Rigel. They'll be big, bright, white supergiant stars. It's going to be very exciting. Will we be here on Earth? Not quite, because the Sun is getting a bit hotter every year. Just a tiny bit, and in a billion years the Earth will be uninhabitable. But maybe humans will have moved to another planet or another moon in the Solar System. And maybe life will be there somewhere looking up into the sky and watching the trillion stars of the new 'Milkdromeda' galaxy twinkling in the night sky.

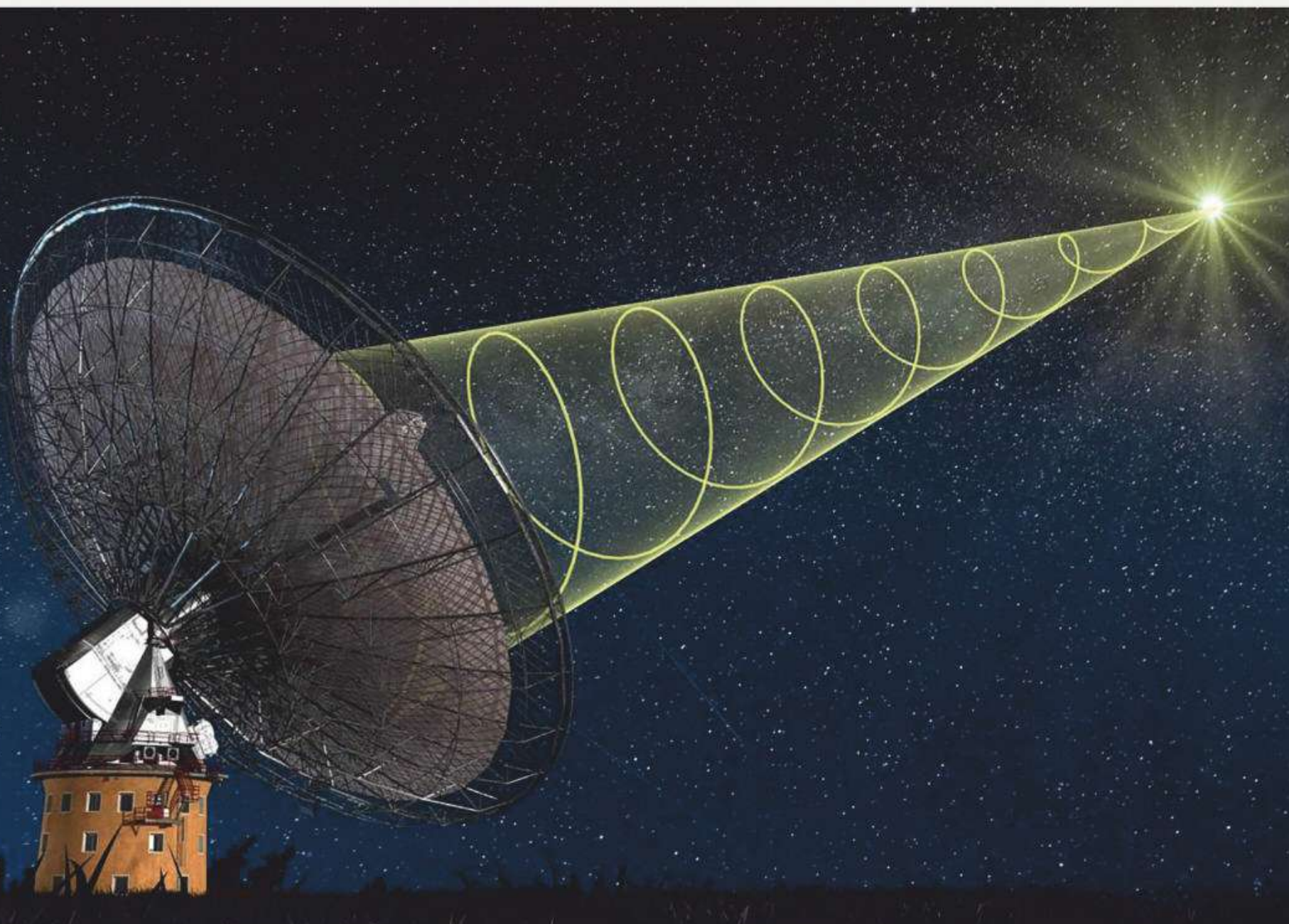
How do you come to this conclusion? Is this based on observations of other galaxies or is this the result of computer simulations?

Both. We look for galaxies that are currently colliding, and you can see loads of them. If you use the Hubble Space Telescope and you look at one piece of sky, you can see thousands of galaxies, and some of them will be smashing together. One beautiful example is the Antennae Galaxies. That is just spectacular and you can see the buckling of the spiral galaxies as they are merging together. You can see how it will evolve.

But also simulations, as you say. With computers we can program a computer to do a 'let's pretend'. Let's pretend two galaxies collide. There are 200

Above:
Astronomers believe the first galaxies were born roughly 200 million years after the Big Bang

Right:
Fast Radio Bursts are unusual and unexpected emissions of radio radiation



billion stars in this galaxy; there are 300 billion stars in the other galaxy. Type the laws of gravity in and it simulates what will happen. It's an incredibly powerful tool for astronomers to then determine what is likely to happen in the future.

Doesn't this idea of the Andromeda and the Milky Way galaxies moving towards each other contradict Hubble's law in the sense that galaxies are supposed to be moving away from each other?

Yeah. It's confusing to a lot of people, and understandably so. Hubble's law, yes - the universe is expanding. And if you look at a galaxy farther away, it's moving away from us faster. Hubble's law can tell us the age of the universe. It's perfection. But there are other factors in there too that we don't always mention in that, which is the fact that gravity works on small scales. When I say small scales - I mean within trillions of light years or so - two galaxies can actually have a gravitational effect on each other. Whereas for galaxies on the other side of the universe, that effect is almost zero. Therefore gravity is irrelevant in terms of the expansion of the universe.

The ASKAP project has had a hand in the recent news regarding Fast Radio Bursts, and more specifically FRB 180924. What are Fast Radio Bursts and why are they such a mystery?

They are really cool. They're huge bursts of radiation that are as strong as a star exploding as a supernova. They're incredibly short-lived. They last less than a millisecond, while other big explosions will last a little while. You imagine a bomb going off or if somebody had dropped something, you can kind of hear the noise for a little while. But these things are just a tiny, tiny flash. [They are] very, very compact and very fast. They happen and then they go away, and they never come back, largely. Recently [astronomers] have started finding ones that repeat, so that's very interesting.

The answer to 'what are they?' We literally don't know. We have no idea. They might be something related to stars and black holes interacting. They might be related to stars colliding, but we just don't know.

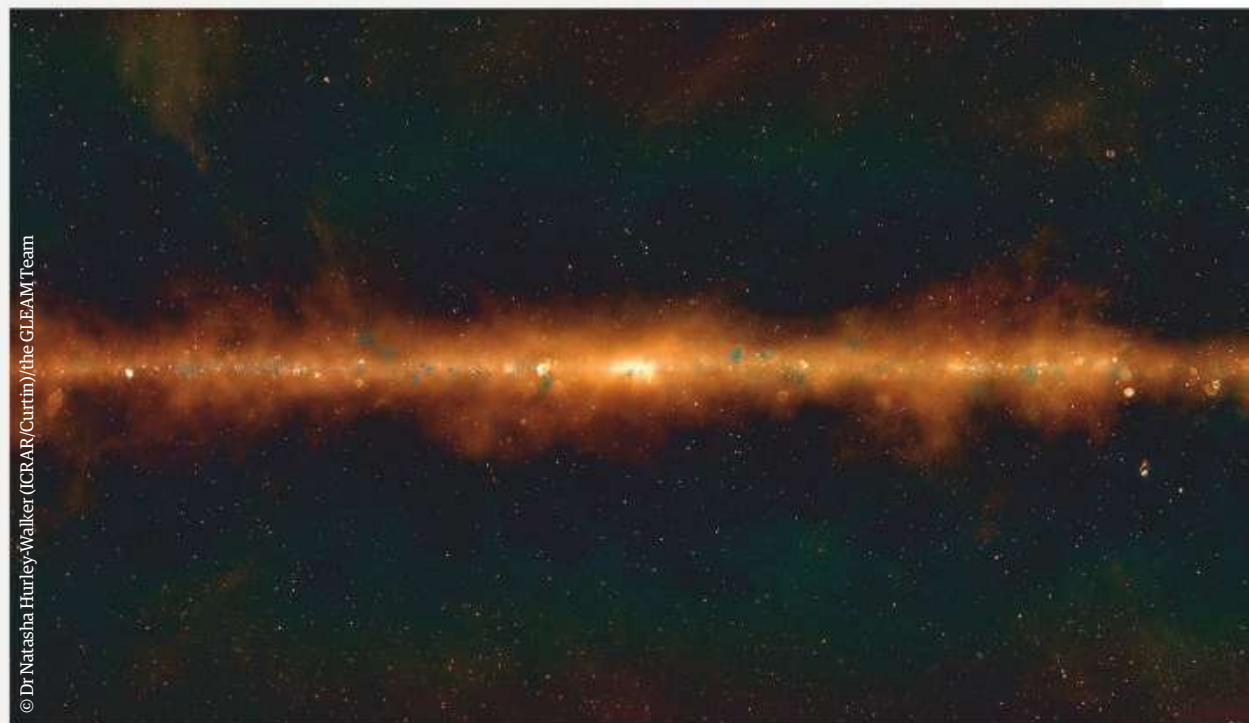
With the recently discovered FRB 180924, it has now had an observed period of activity - lasting around 16 days - and it's even had its location pinpointed to a galaxy. How important is this information for trying to understand these weird cosmic signals?

It's incredibly important. We've been trying to pinpoint them to galaxies since they were discovered, and that's only really been done once or twice now. We can guess how far away they are, and we do that by looking at the colours of light from these flashes.

We know that they are really, really far away.

Right: Observing the night sky in radio waves can reveal a completely different sight.

Below: The Antennae Galaxies, pictured here by the Hubble Space Telescope, are an excellent example of merging galaxies



But these are the first times, with the last couple of Fast Radio Bursts, where it's been able to pinpoint exactly where they are in space. That's really important because that tells us how bright it is. That tells us what kind of process it can be and rules out some of the weaker kinds of explosion that we might think it could be.

Is it kind of like a gravitational wave detection where you receive a detection and then you need to focus all the other available global telescopes on to the source?

That's right. Certainly when the first gravitational wave detection came through from LIGO. I was working at the Australian Telescope National Facility at the time, and I got an email at 02:00 or 03:00 or something. I didn't pick it up because I was asleep, but I was getting calls saying, "Can we get the telescope onto this object?" I think by 06:00 or 07:00 we got there and we're searching the sky for radio signals from this gravitational-wave event. LIGO is doing incredibly well now, so there's lots more of that science going on.

Is there plenty more for radio astronomy to get involved in with that line of research?

Absolutely. We know what gravitational waves are caused by; they are caused by two masses accelerating, and it could be anything. If they're visible to our detectors they are likely to be very heavy and compact stars like pulsars, neutron stars and black holes. By looking at the radio signals to see if there's any emission when, say, stars collide or black holes collide, we can tell what types of objects they are.

When you were researching your book, was there a particular topic within astronomy or astrophysics that you think will see some major revolutions in the future?

Yes. I think our understanding of dark energy is something that will shift very dramatically. This idea that the whole universe is filled with this



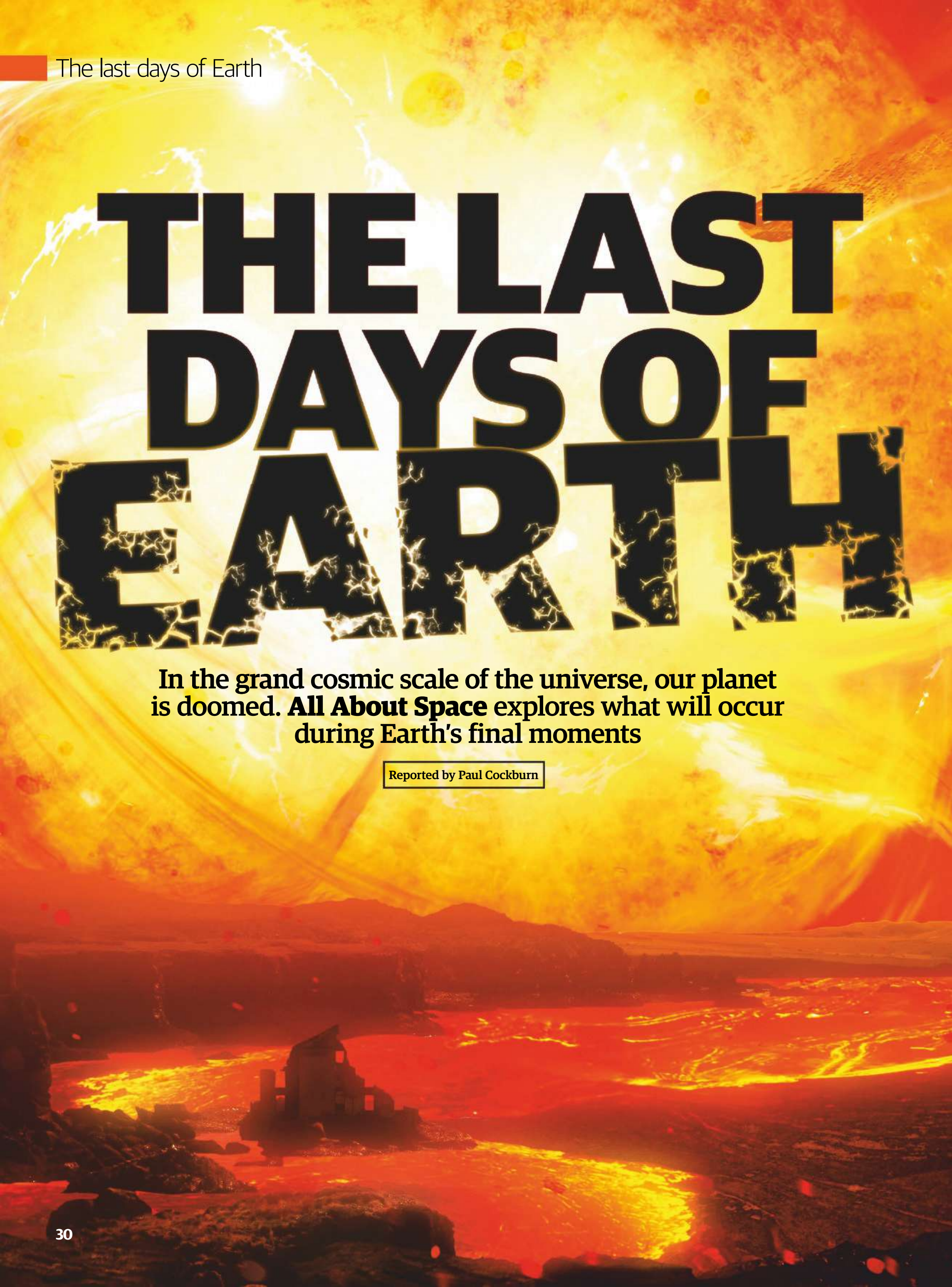
so-called 'dark energy', which is kind of like an anti-gravity, or vacuum energy, but what it means is that it's pushing the universe to expand faster and faster as time goes on. We don't know if dark energy is uniform throughout the universe. We don't know if it's real. We don't know if it's made of particles, or if it's like a field or a force field. We don't know anything about it apart from what we can observe, which is that in the past the universe wasn't expanding as fast as it is today.

That is an amazing mystery. It affects everything in cosmology - about the history of the universe - and it affects where we're going to in the future and whether the universe will expand forever.

Lisa's latest book is available now

Under the Stars: Astrophysics for Bedtime can be ordered on Amazon, Waterstones and at lisaharveysmith.com.





The last days of Earth

THE LAST DAYS OF EARTH

In the grand cosmic scale of the universe, our planet is doomed. **All About Space** explores what will occur during Earth's final moments

Reported by Paul Cockburn



The last days of Earth

Apollo 17 may have been the 20th century's final crewed mission beyond Earth orbit, but its crew left us with one very public legacy - the iconic 'Blue Marble' image of planet Earth, which during the last 48 years has become one of the most reproduced images in human history. Admittedly that's barely a pinprick when compared to the history of life on Earth as a whole: when you consider that the first 'living' molecules appeared some 3.8 billion years ago - and that by current estimates the last are likely to disappear from existence around 3 billion years from now - we're still pretty much the new kids on the block.

Perhaps that explains our insecurity as a species and why we have spent so much of our recorded history predicting the end of the world as we know it - or at least the end of humanity's time on Earth. Even now in 2020, cosmological events including predictable solar eclipses are taken by some people as evidence of an approaching Armageddon, and any new scientific advancements the rapture.

Yet very few scientists would suggest that our home will always be the beautiful 'Blue Marble' photographed by the Apollo 17 crew in 1972. Even assuming that we humans manage to hold out for significantly longer than most mammalian species on the planet have done so - say a few hundred

million years - the small rock that we call home will inevitably become quite a different place during the next few billion years.

In the much-quoted ending to his poem *The Hollow Men*, T. S. Eliot suggested that the world will end "not with a bang but a whimper". In truth it could be either, if by 'bang' you mean an unexpected, catastrophic event that comes 'out of the blue', contrasted with the 'whimper' of the passage of time and ongoing natural evolution. Either could cause existence-threatening devastation at a global level, but clearly these would take place over different time scales.

Certainly there's evidence suggesting that numerous 'bangs' have already happened, even during the planet's relatively recent geological history. Most famously there's the Chicxulub impactor, the comet or asteroid now generally believed to have triggered the mass extinction of three-quarters of Earth's plant and animal species - including non-avian dinosaurs - at the end of the Cretaceous Period.

The Chicxulub impactor is estimated to have been about ten kilometres (6.2 miles) in diameter. There are plenty of comparable objects in the Solar System, but while none are seen as an immediate threat to our planet, there's still the chance that even 'safe' near-Earth objects will have their orbits dangerously deflected in the future. This isn't just in the short term either; some 1.4 million years in the future, the star Gliese 710 will pass within 1.1 light years of the Sun. It's been predicted that this will lead to a five per cent increase in the number of objects originating from the gravitationally disturbed Oort Cloud that are likely to hit Earth.



Left: If a large asteroid strikes a populated area of Earth, it would cause devastation across a wide area

Timeline of our planet's fate

Predictions are never easy, but what is the likely route to Earth's demise?

Present day **An oasis for life**

Earth is the most fertile spot in the known universe, with a protective atmosphere and liquid water in abundance.

Around 300,000 years **Wolf-Rayet star WR 104 would have exploded, killing life on Earth**

Part of a binary star system 7,800 light years from Earth, WR 104 and its companion are expected to turn supernova within the next few hundred thousand years. Depending on WR 104's axis of rotation, any resulting gamma ray burst could be aimed at Earth.

500,000 years **Earth will be hit by an asteroid one kilometre (0.62 miles) wide**

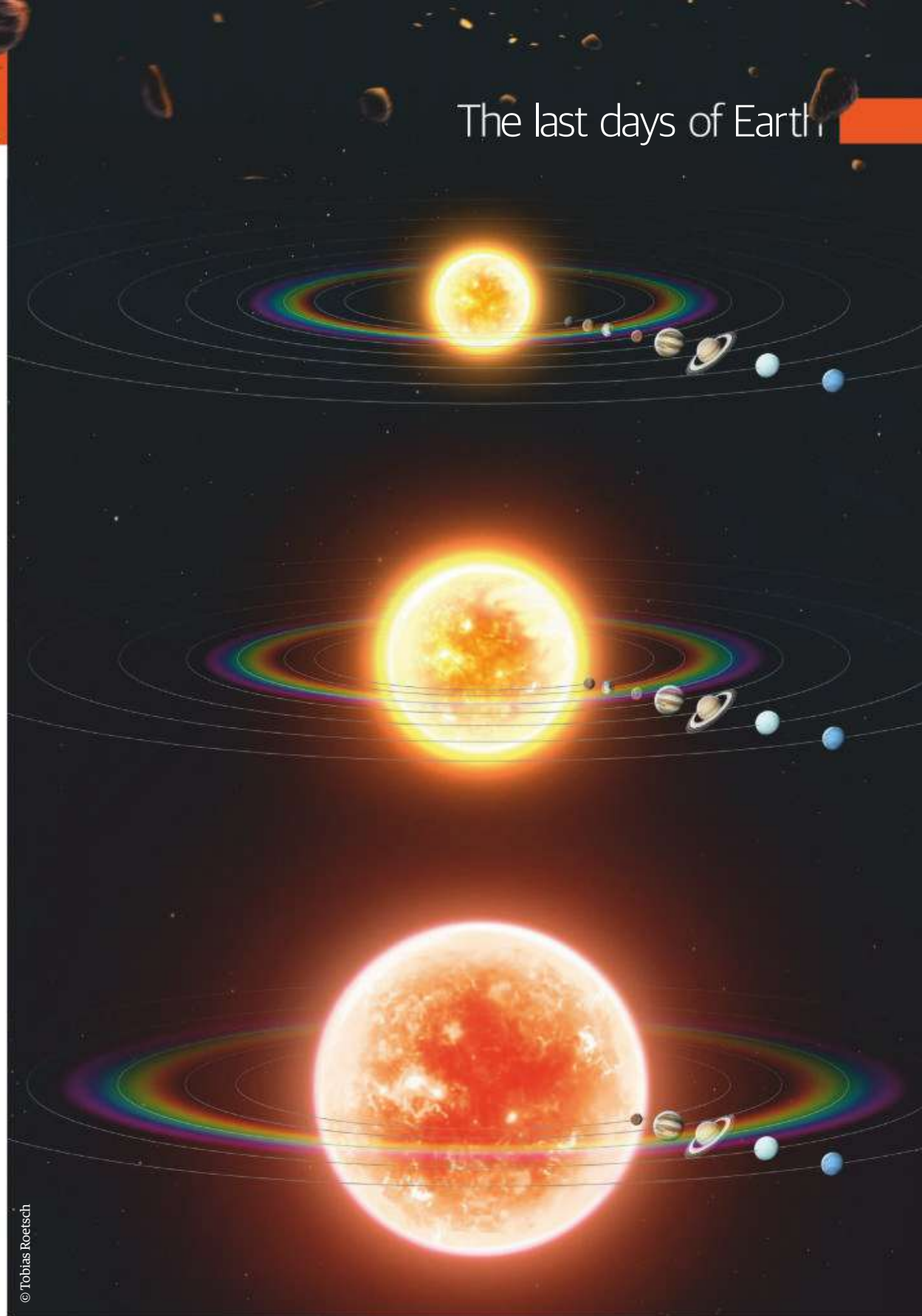
Earth is hit by a large asteroid roughly once every 500,000 years, leading to damage on a potentially global scale. Given sufficient advanced warning, however, it's surely likely that the space technology needed to divert such asteroids could be developed, regardless of cost.

Indeed, the gravity of any massive object - a star, large planet or black hole - could prove catastrophic if it came sufficiently close to the Solar System.

Nor is it just asteroids; back in 2008, two computer simulations of long-term planetary motion in our own Solar System - one by Jacques Laskar of the Observatoire de Paris, the other by Konstantin Batygin and Gregory Laughlin of the University of California - suggested that Jupiter was still enough of a gravitational bully to potentially pull innermost planet Mercury out of its current elliptical orbit and throw it into a collision course with Earth. Other possible fates for the small planet were colliding with Venus, crashing into the Sun or being ejected from the Solar System altogether.

Before you get too worried, however, these models also suggested that there was only a one to two per cent chance of Mercury going for a wander before the Sun bloated in size sufficiently to swallow it up in a few billion years. However, given the global consequences of the Chicxulub impactor, it's clear that nothing would survive the impact of a body some 4,879 kilometres (3,032 miles) in diameter. The last time anything on that scale happened - the hypothesised Mars-sized body astronomers call Theia smashing into the early

Right: The Sun swells into a red giant, swallowing Mercury, Venus and Earth too



© Tobias Roetsch

“THERE'S STILL THE CHANCE THAT EVEN 'SAFE' NEAR-EARTH OBJECTS WILL HAVE THEIR ORBITS DANGEROUSLY DEFLECTED IN THE FUTURE”



10 million years Extinction of plants and animals, mainly due to human activity

Extinctions are an arguably inevitable aspect of life, with a predictable underlying rate against which major extinction events - including human-influence - are contrasted. By this point most species will have become extinct, resulting in a perilous future for any new evolving species.

100 million years An asteroid hits Earth, similar in size to the asteroid that wiped out the dinosaurs

On top of the impact itself, shock waves and debris thrown into the upper atmosphere would cause massive climatic change around the entire globe - assuming, of course, that it wasn't detected in sufficient time to either destroy it or deflect its path.

230 million years Orbit of Earth becomes unpredictable

Lyapunov time is the period after which it's no longer possible to accurately predict the movement of elements in a chaotic system. Named after the Russian mathematician Aleksandr Lyapunov, this is when the cumulative effects of small chaotic factors in the Solar System currently make accurately predicting Earth's orbit impossible.

x6 images © Tobias Roetsch

The last days of Earth

Below: A charred Earth, 7 billion years from now, circling a red giant Sun

Earth some 4.5 billion years ago - the resulting debris was sufficient enough to form the Moon.

Scientists have also suggested a range of more distant cosmological events which could prove equally disastrous: from increases in cosmic dust impacting on comets and asteroids and leading to increased matter falling down on Earth to a statistically rare but decidedly possible gamma-ray burst from a nearby - at least in astronomical terms - supernova. Or, if that's not big enough a threat, a super-luminous supernova - also known as a hypernova - which is ten or more times more powerful than the standard variety.

Some scientists have suggested that just such a hypernova within our own Milky Way Galaxy caused the second-largest extinction seen in Earth's history, the Ordovician-Silurian extinction events which led to the loss of about 85 per cent of all species between 443.8 million and 440.8 million years ago. The theory is that a sufficiently powerful and long burst of gamma rays hit Earth, stripping away at least half of the ozone from Earth's atmosphere and exposing surface-dwelling life - including everything responsible for planetary photosynthesis - to dangerously high levels of ultraviolet radiation.

But what about the whimper? We know that Earth has undergone significant climate change during its existence, including numerous glacial ice ages and potentially at least one period around 650 million years ago when all the oceans were covered by ice - the so-called 'snowball Earth'. A severe change in our existing environment - either hotter or colder - could yet undermine human civilisation. Yet even abrupt changes in the global climate regime are likely to pale in comparison to the

natural evolution of our nearest star. The Sun which gives us life is as equally likely to end it.

James Lovelock is best known for the 'Gaia hypothesis', which he developed with support from microbiologist Lynn Margulis in the 1970s. This proposed that the evolution of our environment and all life on Earth is part of a large, generally self-regulating physiological system. This even included some form of climate control, which Lovelock suggested had ensured the maintenance of an "equable climate" since life had begun.

Yet as far back as 1982, in a scientific paper written alongside Michael Whitfield of the Marine Biological Association, Lovelock had considered ways in which levels of the greenhouse gas carbon dioxide had helped planet Earth to so far resist the warming tendency of the Sun. It was a system that Lovelock suggested might one day be in danger of breaking down.

Compared with when it first started to shine, the Sun we see in the sky today is thought to be about 30 per cent brighter thanks to 4.5 billion years worth of hydrogen in its core being converted into

"EARTH HAS UNDERGONE SIGNIFICANT CLIMATE CHANGE DURING ITS EXISTENCE, INCLUDING NUMEROUS GLACIAL ICE AGES"

© Science Photo Library



500 to 600 million years Nearby gamma-ray burst or hypernova strips Earth's ozone layer

This is the estimated time by which a gamma-ray burst from a supernova or hypernova located within 6,500 light years of Earth will strip away much of Earth's ozone layer, potentially triggering a mass extinction. This assumes, however, that the supernova burst will be precisely aligned with Earth.



600 million years Sun's increased luminosity affects Earth

Energy levels from the Sun begin to unbalance the carbonate-silicate cycle, which sees the increased trapping of carbon dioxide in carbonate rocks. Rocks harden, causing plate tectonics to slow and eventually stop, while falling carbon dioxide levels lead to the extinction of much plant life.



1 billion years Earth's surface temperature gets hotter

Reaching 47 degrees Celsius (116.6 degrees Fahrenheit), the evaporation of oceans will create a 'moist greenhouse' atmosphere. A proportion of the water vapour will reach the stratosphere and beyond where sunlight will split it into its constituent atoms, the hydrogen lost to space.

helium via nuclear fusion. The heavier element has increased the pressure at the Sun's core and heated up the rate of the nuclear reactions, so it shines much more brightly.

Currently accepted theories about the evolution of main sequence stars - and our Sun is a very standard example - suggest that this energy output will continue to increase over time. Not even the Sun beginning to run out of hydrogen fuel in a few billion years' time is likely to stop more energy hitting Earth, with very real consequences for life on the planet as average temperatures rise, affecting the environment and wildlife.

The fading energy derived from the fusion of hydrogen into helium will no longer be enough to hold back gravity, meaning the core of the Sun will begin to shrink. However, it's believed that the shrinking will maintain the core's internal pressure enough to ensure the remaining hydrogen outside the core burns even faster. That in turn will increase both the pressure in the core and the rate at which hydrogen is fused into heavier elements.

Currently our Sun is about halfway through the shift from burning hydrogen at its heart to burning the hydrogen in a spherical shell wrapped around an intensely hot, very dense helium core. Once the Sun makes that transition, however, it'll be entering its twilight years - not that it'll get darker.

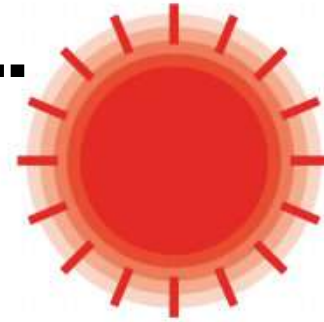
Thanks to gravitational pressure, the nuclear furnace at the heart of the Sun will slowly begin to overheat, reaching extreme temperatures where the helium can undergo nuclear fusion to form heavier elements. Energy released in the process will see the Sun expand into a red giant that will undoubtedly swallow up Mercury and Venus - and could even swallow Earth and Mars. Even if our

How can we...



...avoid an asteroid impact

The Minor Planet Center in Cambridge, Massachusetts, has been cataloguing asteroid and comet orbits for over 70 years. Proposed strategies involve breaking up asteroids so they burn up harmlessly in the atmosphere or delaying arrival times so they miss Earth.



...escape an expanding red giant Sun

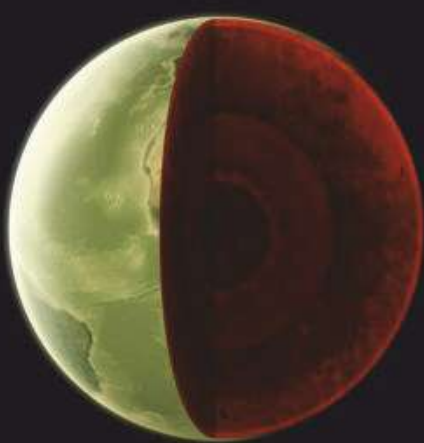
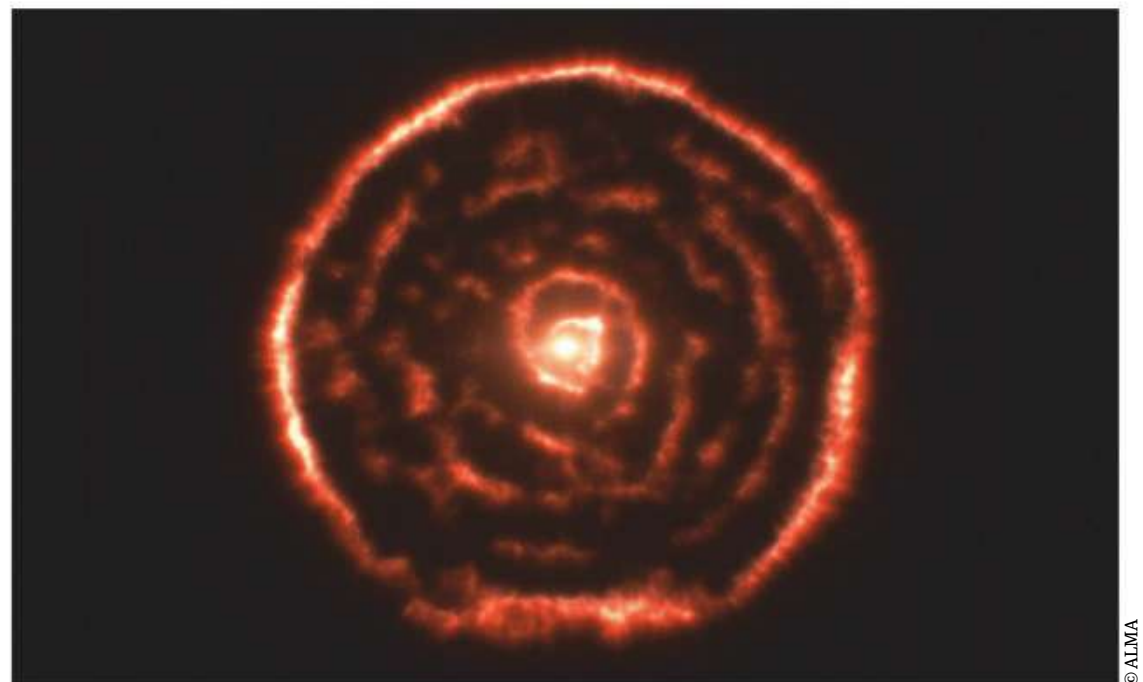
If we could push Earth just a little bit further out from the Sun - say, an additional 15 per cent - it's been suggested that it would definitely survive the furthest reach of the Sun's expansion into a red giant, although it still wouldn't be a viable place on which to grow crops.



...avoid a runaway greenhouse effect

In the long term, this looks unavoidable. Once the Sun's luminosity overtakes Earth's ability to dissipate absorbed radiation into space - from 1 to 3 billion years from now - temperatures will steadily rise until most of Earth's oceans evaporate into water vapour.

Right: Spiral structure around R Sculptoris, a red giant star 1,500 light years from Earth



2.3 billion years Earth's magnetic field shuts down

The freezing of Earth's outer core shuts down Earth's magnetic field, with drastic consequences for any remaining life on the planet as there is nothing to deflect the DNA-damaging, potentially deadly cosmic rays and solar wind. The latter would also strip away any remaining atmosphere, leaving the surface totally defenceless.



2.8 billion years Entirety of Earth is scorching hot

By this point Earth's environment is hostile to any multicellular life, but when global temperatures - even at the poles - reach an average of 147 degrees Celsius (297 degrees Fahrenheit), even the last remaining unicellular life on the planet - in isolated refuges such as high-altitude lakes or cold-trap caves - can no longer survive.

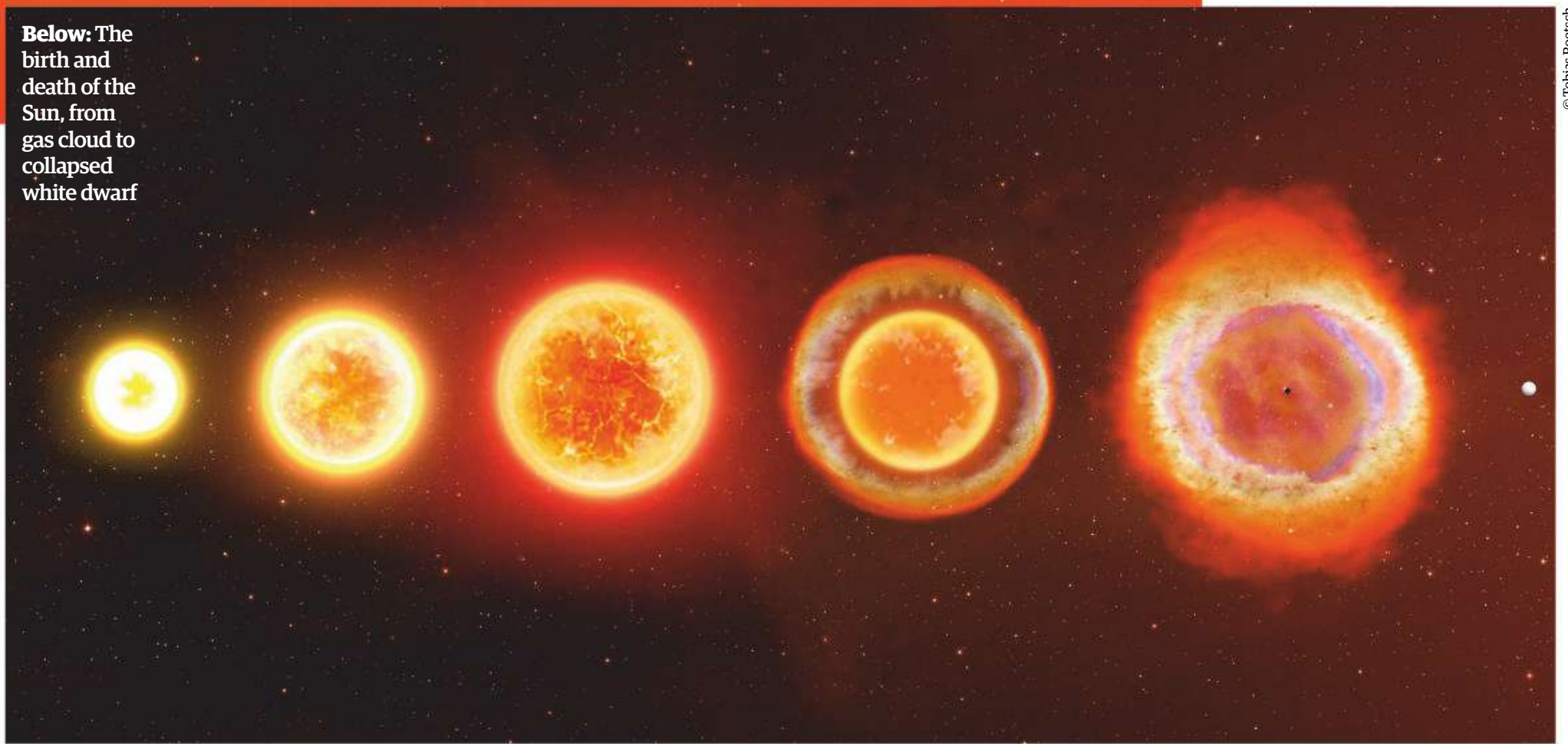


3 billion years Moon becomes unstable and Earth's poles become chaotic and extreme

The Moon has long been moving away from Earth - at roughly four centimetres (1.6 inches) a year - but this is the point at which it is sufficiently distant to no longer effectively influence Earth's axial tilt, resulting in the planet's true poles increasingly 'wandering' as its spin becomes less stable.

The last days of Earth

Below: The birth and death of the Sun, from gas cloud to collapsed white dwarf



© Tobias Roetsch

planet physically survives this expansion, however, it will no longer be that precious and recognisable Blue Marble - it will be a charred rock no longer capable of supporting even single-celled life. Its oceans and atmosphere will boil away into space, although not before contributing to rising global surface temperatures capable of melting stone.

Assuming that humans are still around in some form, it's extremely unlikely we'll still be living on Earth by that point. We'll likely have moved further out, perhaps to the moons of the gas giants that will by then be well within the bloated Sun's habitable zone. We might explore even further in search of

"THE FADING ENERGY WILL NO LONGER BE ENOUGH TO HOLD BACK GRAVITY, MEANING THE CORE OF THE SUN WILL BEGIN TO SHRINK"

exoplanets beyond the Solar System that we can make into our very own Earth 2.0.

Unexpected catastrophes notwithstanding, the end of life on Earth certainly won't be a simple decline into nothing. As the continental plates continue to move, as mountains rise and are eroded away, as continents move and change, new

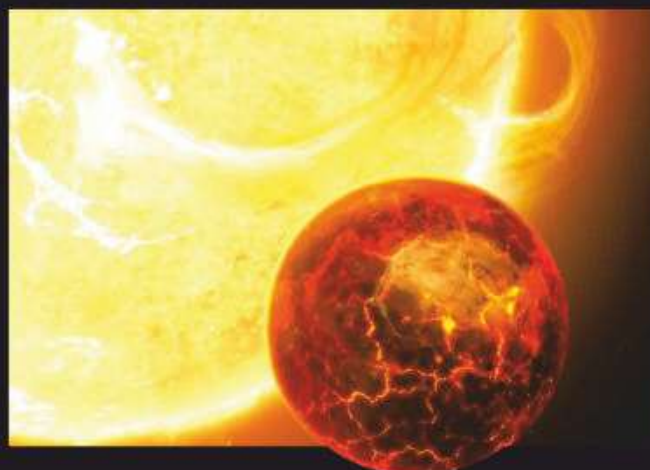
species may well evolve to fill some much-changed ecological niches.

None of this will happen the day after tomorrow, so don't get too worried about it all. Besides, we're arguably the one species on the planet that - through science and technology - might just be capable of giving ourselves a stay of extinction.



3.3 billion years **Mercury or Venus could collide with Earth**

There is a one to two per cent chance that Jupiter's long-term gravitational influence on the inner Solar System makes Mercury's orbit so eccentric that the small inner world might collide with the gassy Venus or even come as far as Earth, crash into the Sun or be ejected from the Solar System entirely.



3.5 to 4.5 billion years **Surface heats to 1,130 degrees Celsius (2,066 degrees Fahrenheit)**

Water vapour in Earth's lower atmosphere increases to 40 per cent. This, combined with the Sun now being 40 per cent brighter than in the 21st century, leads to a rampant runaway hothouse environment with surface temperatures hot enough to melt rock. Essentially it's a hotter version of today's Venus.



7.5 billion years **Earth and Mars become tidally locked with an expanding subgiant Sun**

Having one side of a planet constantly facing the Sun leads to more than just temperature differences between the two sides; any remaining atmosphere will necessarily move between the light and dark faces, creating storms and causing serious landscape erosion - not good for continued life in any form.



Earth as it might look following extreme climate change or another catastrophe

© Science Photo Library



7.59 billion years Moon falls towards Earth, breaking into debris that rains on it

Orbital drag in the vicinity of the Sun's apparent surface - the photosphere - reduces the Moon's orbit until it reaches the point where the gravity holding it together is weaker than the tidal forces pulling it apart. Earth will again briefly have a ring of debris before it falls down on the planet.

7.59 billion years Earth falls into the Sun at red giant phase

Reaching its maximum size as a red giant - a radius 256 times its present-day value - the Sun swallows up Mercury and Venus, very likely Earth and possibly even Mars. On the plus side, by then Saturn's moon Titan will likely have the precise surface temperatures needed to support life.

x5 images © Tobias Roetsch

FLOATING COLONIES ON VENUS

High above the carbon-dioxide-laden clouds, this planet could turn from hostile to relatively hospitable for future astronauts

It's incredibly hot, with a searing average temperature of over 460 degrees Celsius (860 degrees Fahrenheit). Its atmosphere is thick with choking carbon dioxide, laced with poisonous sulphuric-acid clouds that hang above a parched desert-like landscape, renewed by the angry eruptions of volcanoes. Without a doubt Venus - with its additional high-pressure environment that has a crushing power almost 100 times that of Earth's - is unfriendly for life. Sending astronauts to a world that can cook, crush and choke in just a few seconds and hoping they survive is ambitious to say the least.

However, according to some - such as Geoffrey Landis of NASA's Glenn Research Center - where there's a will there's a way. In a concept that sees fiction meet science, Venus could be the next go-to destination for colonisation. Forget attempting to touch down on the parched, unpredictable surface. Forget trying to pass through the suffocating atmosphere. There's a new concept, and it's straight from the pages of futuristic novels. Floating cities akin to levitating island Laputa of *Gulliver's Travels* fame or airborne habitats are the new way forward, creating an unusual twist that would see humans living relatively comfortably in hostile conditions, surfing above the surface.

In general Venus is unfit for habitation, but some 50 kilometres (31 miles) above the surface a different story is told: the dense carbon-dioxide atmosphere gives way to an environment similar to our own as it cools down to somewhere between 0 and 50 degrees Celsius (32 and 122 degrees Fahrenheit) and the pressure is a more forgiving one bar. However, even in these

conditions we would not be able to wander around quite as comfortably as we do here on Earth. The air is still toxic for us to breathe and the acid that rains down would spell disaster. But with a supply of air and the right protection, this is a seemingly small hurdle to overcome.

According to Landis, getting a city the size of New York to float might seem like a far-flung idea, but with the simple premise of buoyancy it might actually be feasible. It's just a question of finding some type of lifting gas, Landis says, and that gas is the nitrogen and oxygen found in our own atmosphere. When the air we breathe meets with carbon dioxide, floating occurs, bringing a lifting power just over half that of helium, which we know is what gives hot-air balloons their effortless flight. Using the same principle, floating colonies are envisioned with breathable air domes to lift a city off the ground, with storage tanks of readily available hydrogen and helium allowing the lifting power to be adjusted. The problems faced by a Venusian colony at first glance seem to gradually disappear as it slowly builds height in Venus' skies.

Further still, hanging above the carbon-dioxide-laden clouds, solar panels could take advantage of the sunlight reflected from the thick atmospheric smog, providing almost twice the energy Earth can from above its cloud layer. The 400 kilometre (250 mile) per hour winds that rage around Venus' circumference and provide this terrestrial planet with its so-called superrotation sweep up even more power for these levitating platforms. Venus might be unwelcoming, but with these tricks to avoid its hostility, why shouldn't we head to the second planet from the Sun?

Toxic air and acid

Future colonists of Venus can throw away their pressurised suits, but the air is still toxic to breathe and the sulphuric acid that rains down will dissolve whatever it comes into contact with - we would still need a supply of air to breathe and suitable protection.

Earth-like atmosphere

Some 50 kilometres (31 miles) above the surface, the conditions are similar to Earth. The temperature drops somewhere in the region between 0 and 50 degrees Celsius (32 and 122 degrees Fahrenheit) and the pressure is a less compressing one bar.

Hostile yet useful

Venus' atmosphere might be unfriendly, but it could also provide an additional lifting gas – such as hydrogen or helium – that could be extracted from it.

Mixing with safety

Since there is no significant pressure difference between the inside and outside of the balloon, colonies can expect no rapid deflation, allowing enough time to repair any rips or tears.

Solar panels

So high up in the Venusian atmosphere, the colony is able to make use of reflected sunlight – harvested by solar panels – from the clouds, which provide almost twice the energy supplied by Earth's cloud layer.

A large colony

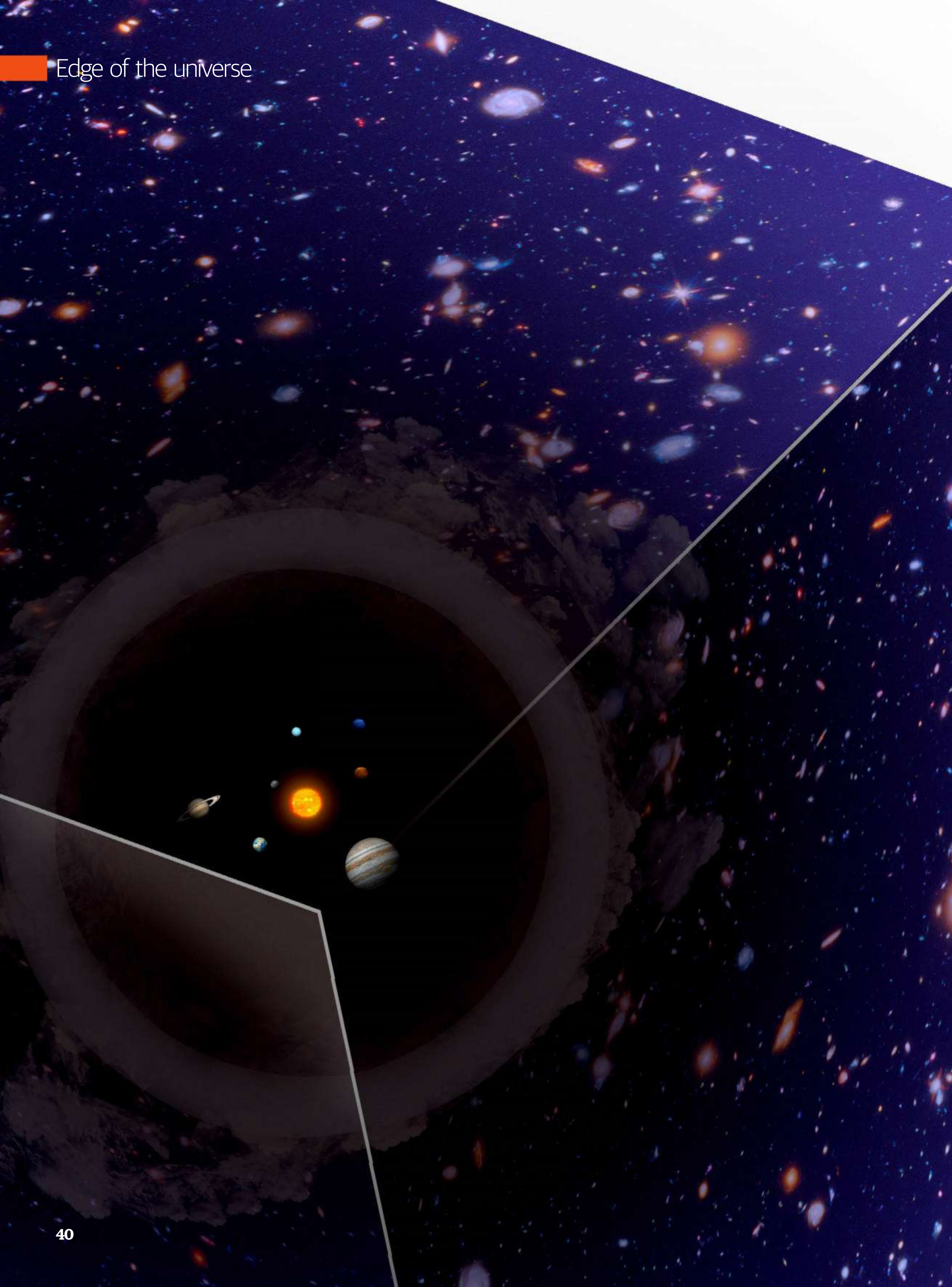
It is thought that creating a floating city the size of New York could be possible.

Untethered

Releasing it from its post and allowing it to move freely with the moving atmosphere would reduce structural stress from the buffeting winds above the clouds.

Staying afloat

A balloon full of human-breathable air would be able to keep an entire colony floating, serving as a lifting gas in the denser carbon-dioxide atmosphere of the planet.



Edge of the universe



© NASA/ESA & Hubble

WHETHER OR NOT OUR COSMOS COMES TO AN END IS A QUESTION ASTRONOMERS ARE TACKLING WITH SOME SURPRISING RESULTS

Reported by Colin Stuart

Look out on a clear night and you can see pretty far into the universe. Some of the stars you'll spot sit over 10,000 light years from Earth. Even further away is the famous Andromeda Galaxy, the nearest major star city to our own Milky Way and debatably the most distant object you can see with your eyes alone. It is a staggering 2.5 million light years from us. That means the light arriving on Earth today from Andromeda has been trekking across space for 2.5 million years to get here. All of human history has played out in the time it's taken for light to reach us from just our nearest galaxy. With binoculars and telescopes you can continue to see objects further and further from home. But where does it all end? Does it even end? "We just don't know," says Andrew Pontzen, a cosmologist at University College London. "There is no evidence for an edge to the universe, but there is an edge to what we can see." We can only see

Where does it all end?

Cosmologists have put forward several different scenarios for where our universe ends

The universe goes on forever

The universe could be infinite in extent, endlessly continuing in all directions, on and on beyond our cosmic horizon with no edges or boundaries. If this picture is accurate then the universe has no edge, and it gives rise to the idea that eventually the same configuration of atoms would repeat in the universe. This means that there is another Earth and another you out there somewhere in the universe right now.



© NASA/ESA & Hubble

Other universes

If cosmic inflation really happened – the super-rapid expansion of our universe in its earliest moments – then it may have happened more than once, giving rise to neighbouring universes. According to Albanian-American cosmologist and theoretical physicist Laura Mersini-Houghton at the University of North Carolina at Chapel Hill, our nearest universe must be more than 1,000-times further than what we understand to be our cosmic horizon.



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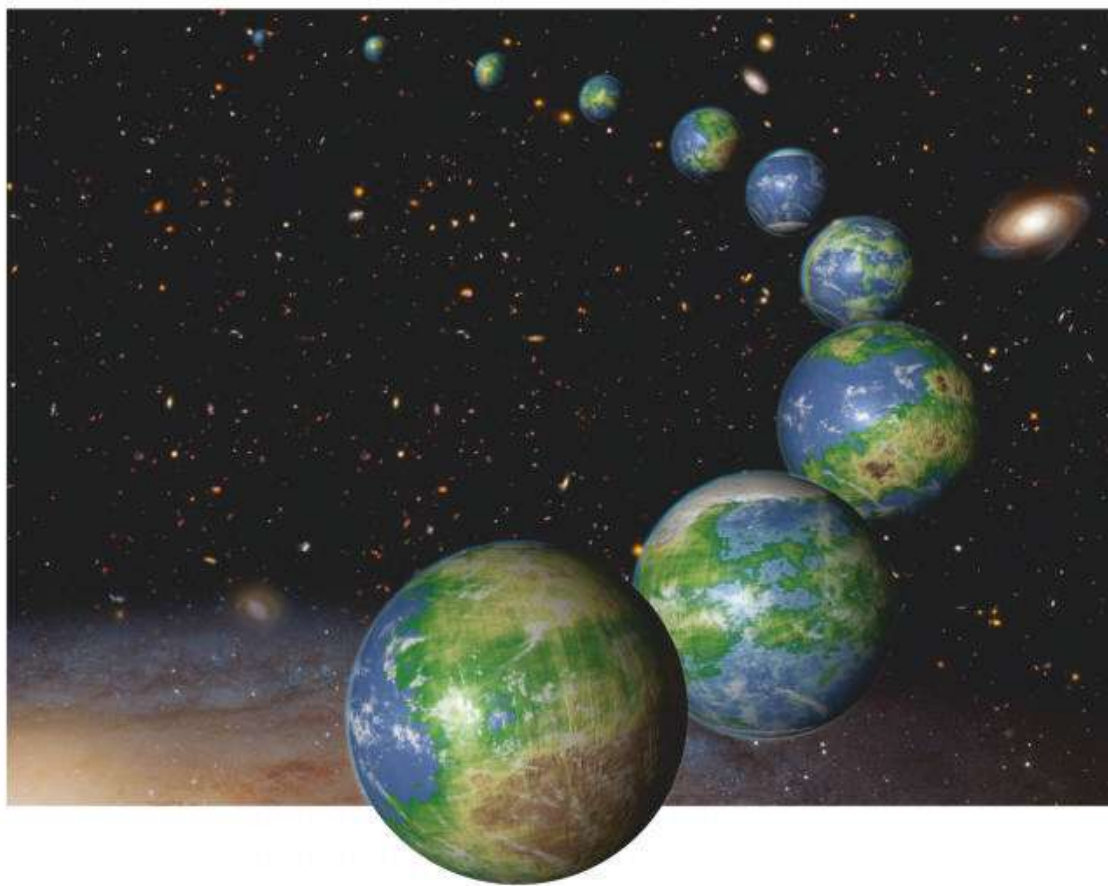
An event horizon

It is possible that what we see as our universe is the remnant of a black hole forming in another universe. One of the leading proponents of this idea is Polish theoretical physicist Nikodem Poplawski. If he's right then just like the surface of Earth, our universe has no edge.



There could be nothing

There is no current reason to suspect that the universe ends with our cosmic horizon, just as we know that Earth doesn't end just because the rest of the planet is hidden from view by its curvature. However, the universe could just stop.



© NASA/ESA

Above: In an infinite universe there are infinite copies of Earth and infinite copies of you

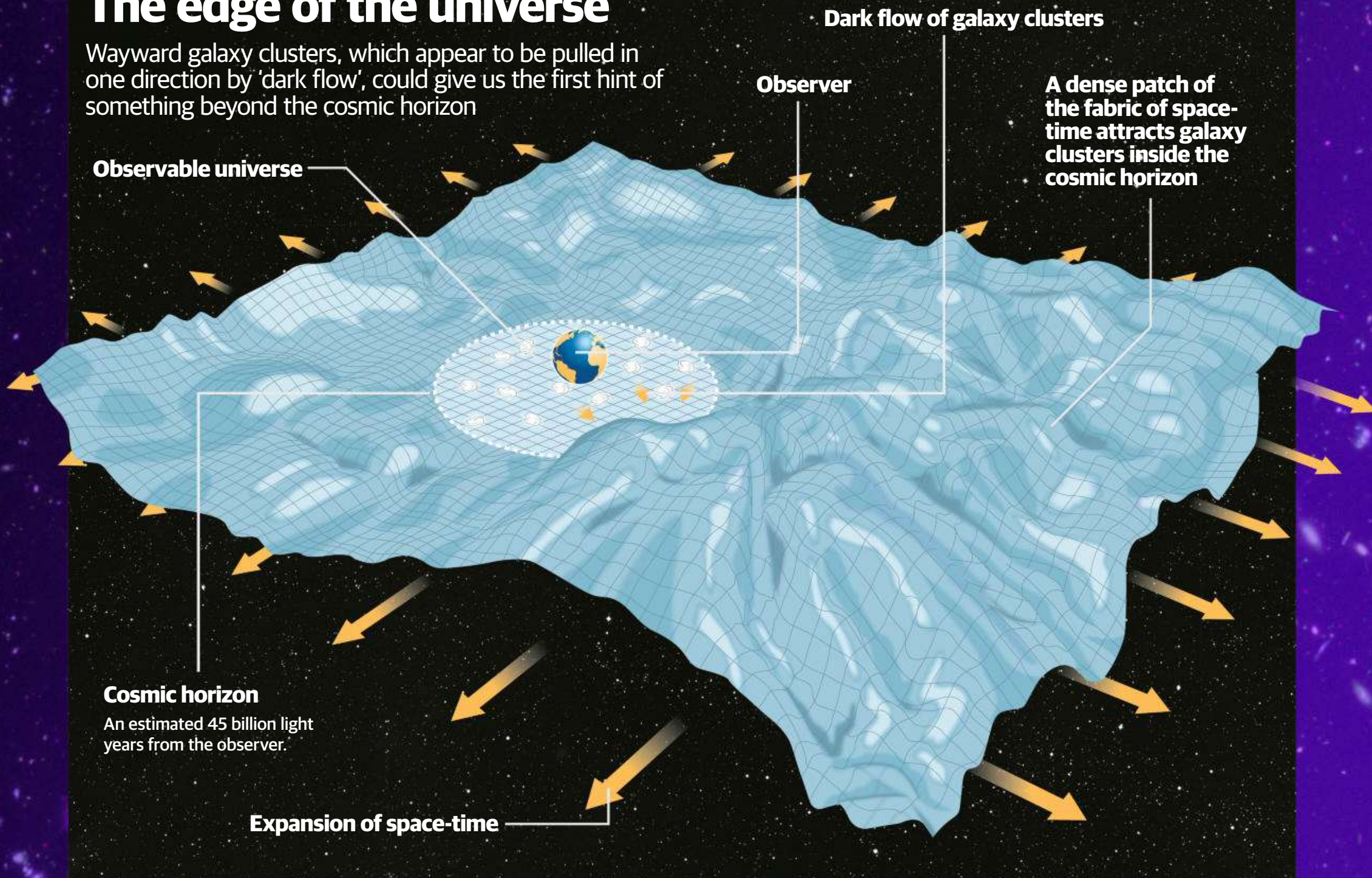
objects in space if the light from those objects has had enough time to reach us. For Andromeda that time is 2.5 million years, but for increasingly more distant galaxies that travel time also increases. There are galaxies so far away that light hasn't managed to make it here yet. This marks out the edge of our visible universe – the part of it we are able to see – but not the end of the universe itself. "It's rather like how you can't see over the horizon but the Earth doesn't end there," Pontzen says. In theory, each passing day should bring with it new light allowing us to push our cosmic horizon outwards. Yet it doesn't quite work like that.

"The longer you wait, the further you should be able to see," says Pontzen. "However, the expansion of the universe is beginning to speed up quite noticeably because of the mysterious stuff we call dark energy." This increased expansion is carrying parts of the distant universe ever more quickly away from us, and there will come a point when we'll have seen as far as we'll ever be able to see. But what is likely to be beyond that visible horizon? Quite possibly more of the same. Some astronomers subscribe to the idea of an infinite universe – one that continues on forever with no edge or boundary. That has led some to a rather disturbing conclusion – there could be exact copies of you out there.

Imagine you had six dice and you rolled them a million times. There are only 46,656 different ways those six dice can be rolled. Just as there are a limited number of ways you can arrange six dice, there are also a limited number of ways you can arrange atoms in the universe. In an infinite universe you're effectively rolling the dice an infinite number of times. Just as the same pattern is likely to crop up multiple times in a million dice rolls, the exact way the atoms in your body are configured is guaranteed to repeat in an infinite universe. That means there is a copy of you on a

The edge of the universe

Wayward galaxy clusters, which appear to be pulled in one direction by 'dark flow', could give us the first hint of something beyond the cosmic horizon



copy of Earth, reading a copy of this article. In fact, in an infinite universe there are an infinite number of copies of you. However, they are almost certainly located beyond our visible horizon, and so you'll never encounter your doppelganger.

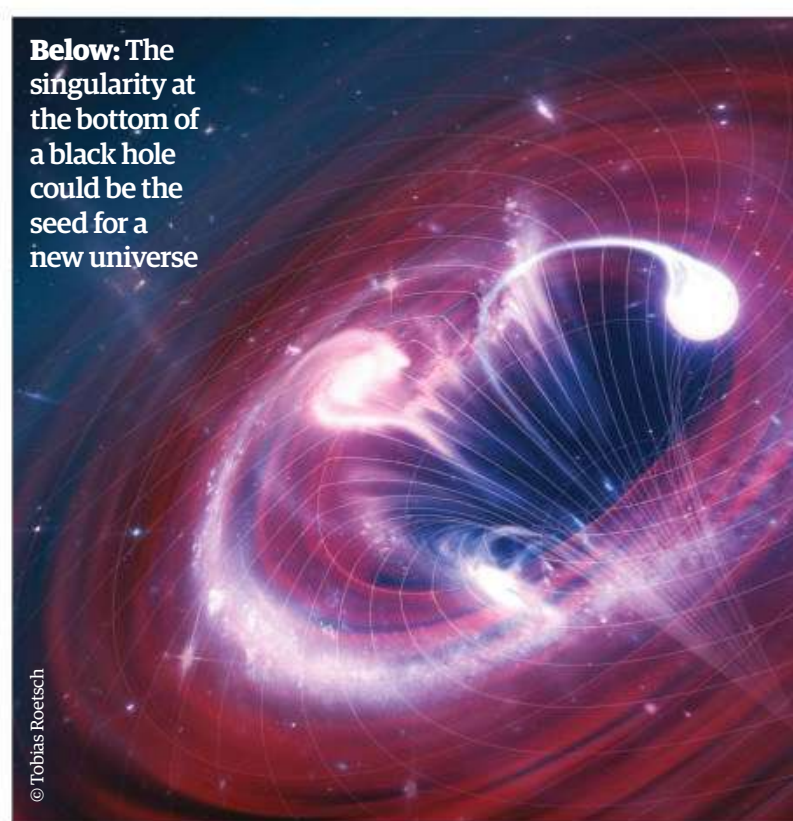
This is one version of the multiverse idea. Effectively you go far enough away in our universe that the cosmos begins to repeat itself and you get multiple copies of the same thing. But there is another version of the multiverse idea, and according to one of its leading proponents it could tell us more about the edge of our universe. Laura Mersini-Houghton is a theoretical physicist at the University of North Carolina at Chapel Hill. Not only does she believe other universes exist, she also thinks she's found evidence of a neighbouring universe interfering with our own.

It all comes down to the cosmic microwave background (CMB) - the afterglow of the Big Bang

which spawned our universe 13.8 billion years ago. It is a temperature map of the background of empty space showing how the leftover energy from the Big Bang is still slightly warming the universe. The map contains small deviations from the background temperature - tiny hot and cold spots - except one of the cold spots isn't so tiny. "It covers about ten degrees in the sky," says Mersini-Houghton. The rest of the hot and cold spots are no bigger than a degree. So where did it come from?

According to the leading idea about what happened around the time of the Big Bang, space underwent a stupendous surge in growth in an insanely short period of time. In the first trillionth of a trillionth of a second, the universe grew from something much smaller than an atom to about the size of a marble. It then continued to expand into the universe we see today, but at a more sedate, albeit still rapid pace. This initial

Below: The singularity at the bottom of a black hole could be the seed for a new universe



The size of the universe

The observable cosmos is not the whole story when astronomers consider how big the universe really is

The cosmic microwave background (CMB) is the furthest that astronomers are able to see from Earth. This ancient light was released when the universe was approximately 380,000 years old, and has been travelling across the cosmos ever since. The furthest galaxies we can see are almost as far away as the CMB - some 13.8 billion light years away. At least that is where they were when the light originally set off. While their light has been making its way to Earth, the universe has carried that part of space ever further from us. That point is now around 45 billion light years away, in effect making the observable universe around 90 billion light years across.

Big Bang

Time: 13.8 billion years ago

Radiation era

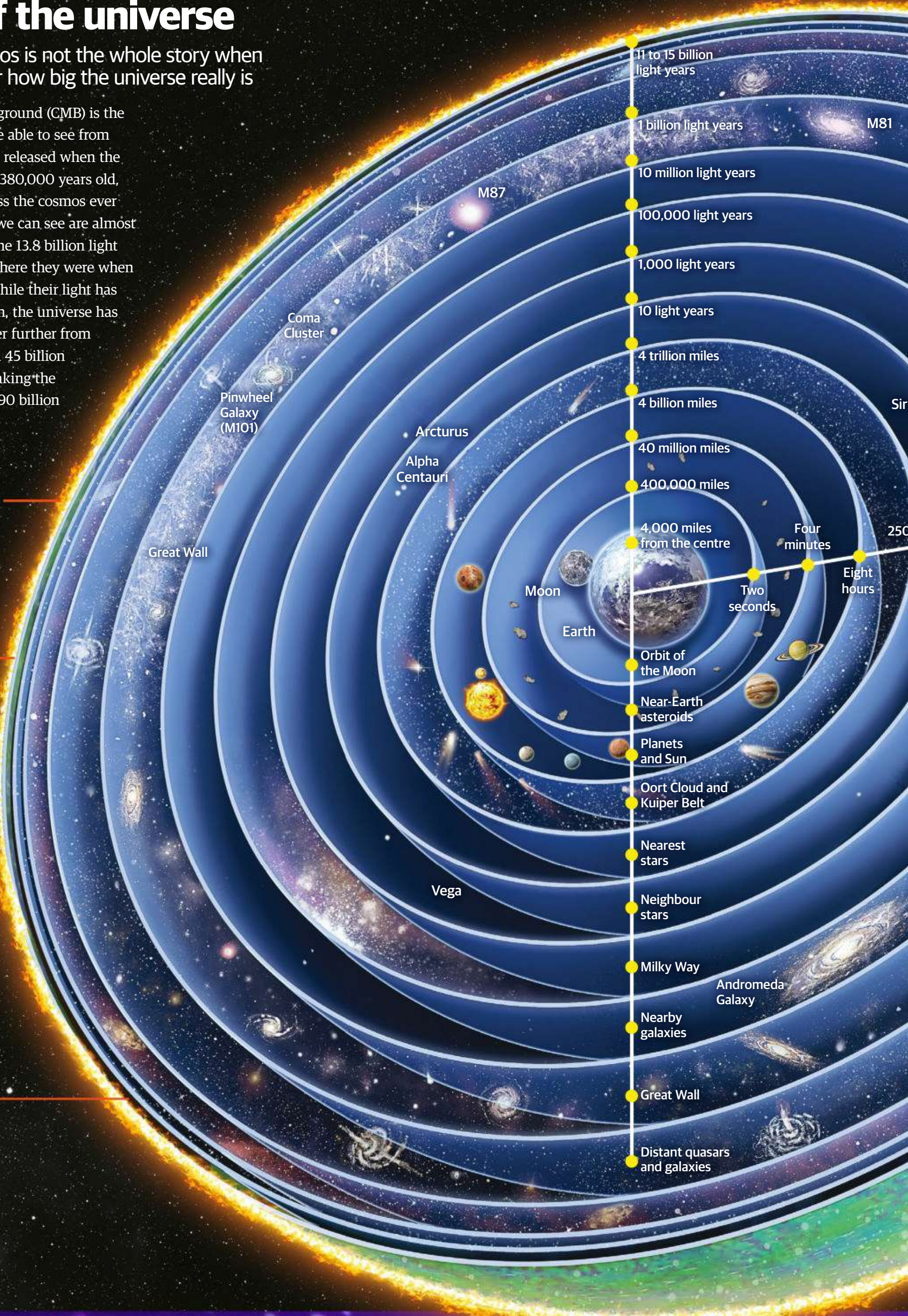
Time: 13.8 to 13.79 billion years ago

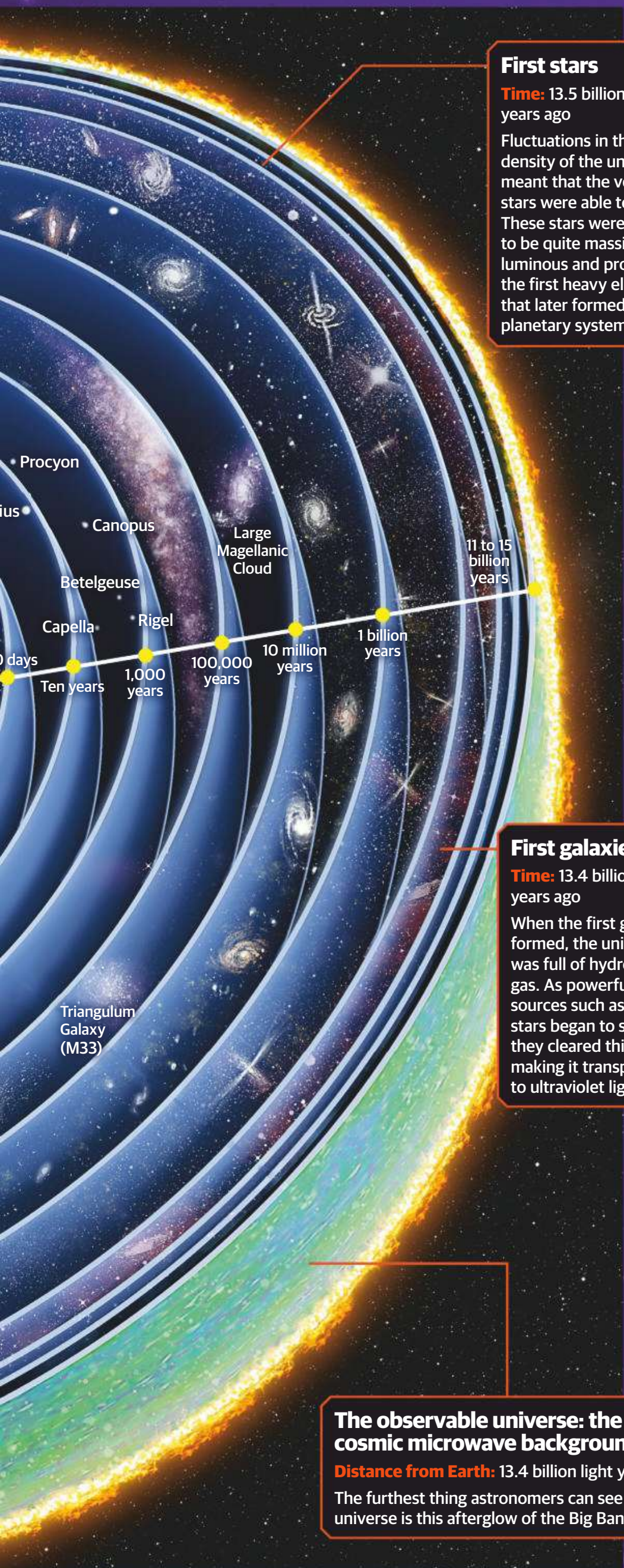
The radiation era began some two or three minutes to 300,000 years after the Big Bang in a process known as nucleosynthesis. At this stage helium nuclei were formed out of protons and neutrons.

Dark ages

Time: 13.79 to 13.5 billion years ago

At this point in the universe's history the cosmos was opaque and foggy. It's thought that the Dark Ages lasted between 150 million and 800 million years after the Big Bang.





First stars

Time: 13.5 billion years ago

Fluctuations in the density of the universe meant that the very first stars were able to form. These stars were likely to be quite massive, luminous and produced the first heavy elements that later formed planetary systems.

First galaxies

Time: 13.4 billion years ago

When the first galaxies formed, the universe was full of hydrogen gas. As powerful sources such as early stars began to shine, they cleared this mist, making it transparent to ultraviolet light.

The observable universe: the cosmic microwave background

Distance from Earth: 13.4 billion light years

The furthest thing astronomers can see in the universe is this afterglow of the Big Bang.

period of 'expansion on steroids' is known as cosmic inflation. According to inflationary theory, the small temperature variations in the CMB are the result of tiny quantum fluctuations during the pre-inflation phase which were frozen into the universe when it ballooned. As these quantum fluctuations were random and approximately equal in size, so should be the hot and cold spots they caused. That's why the presence of one particularly large cold spot has cosmologists scratching their heads. "It's a very significant breaking of the expected uniformity of the CMB," explains Mersini-Houghton.

Her explanation is radical and is by no means accepted by all cosmologists, but it may help us answer the question of where our universe ends. According to one version of inflationary theory, the process didn't just happen once. "Many other universes were created, which are similar to ours," she says. Before each of these universes inflated they would have shared a quantum link between them. "We traced forward that quantum link to see what it would look like at present," she says. The outcome of her calculations was the prediction of a cold spot in the CMB. Crucially, Mersini-Houghton and her team made this prediction public before the cold spot was identified beyond reasonable doubt. Not all cosmologists are convinced, however. "The overall consensus [within the cosmological community] is that the current data doesn't support it," Pontzen says. "It's one of those cases where an extraordinary claim requires extraordinary evidence." Nevertheless, Mersini-Houghton has been able to suggest where the edge of our universe might be if she is right. Her answer? "It is at least 1,000-times further from us than the edge of our cosmic horizon," she says.

She isn't the only one pushing the boundaries of our cosmological thinking and suggesting a potentially revolutionary interpretation of the universe in which we live. Nikodem Poplawski at the University of New Haven, Connecticut, is another physicist challenging our perceived wisdom. "According to general relativity the Big

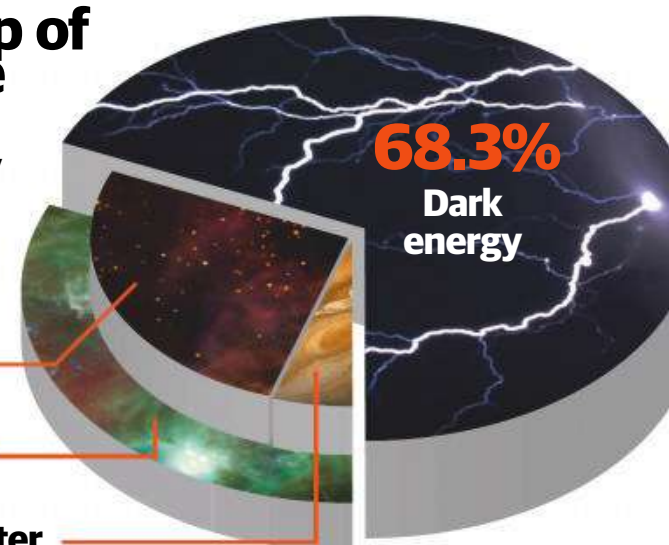
The make-up of the universe

Because the modern universe is dominated by dark energy our cosmic horizon is limited

26.8% Dark matter

31.7% All matter

4.9% Normal matter

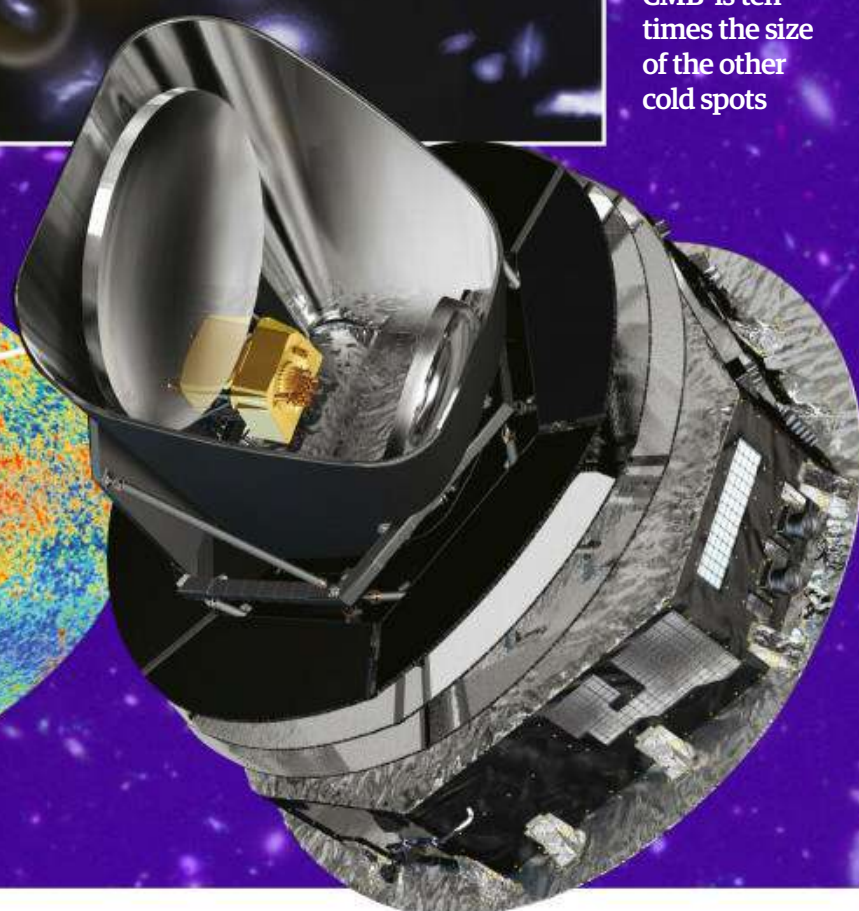
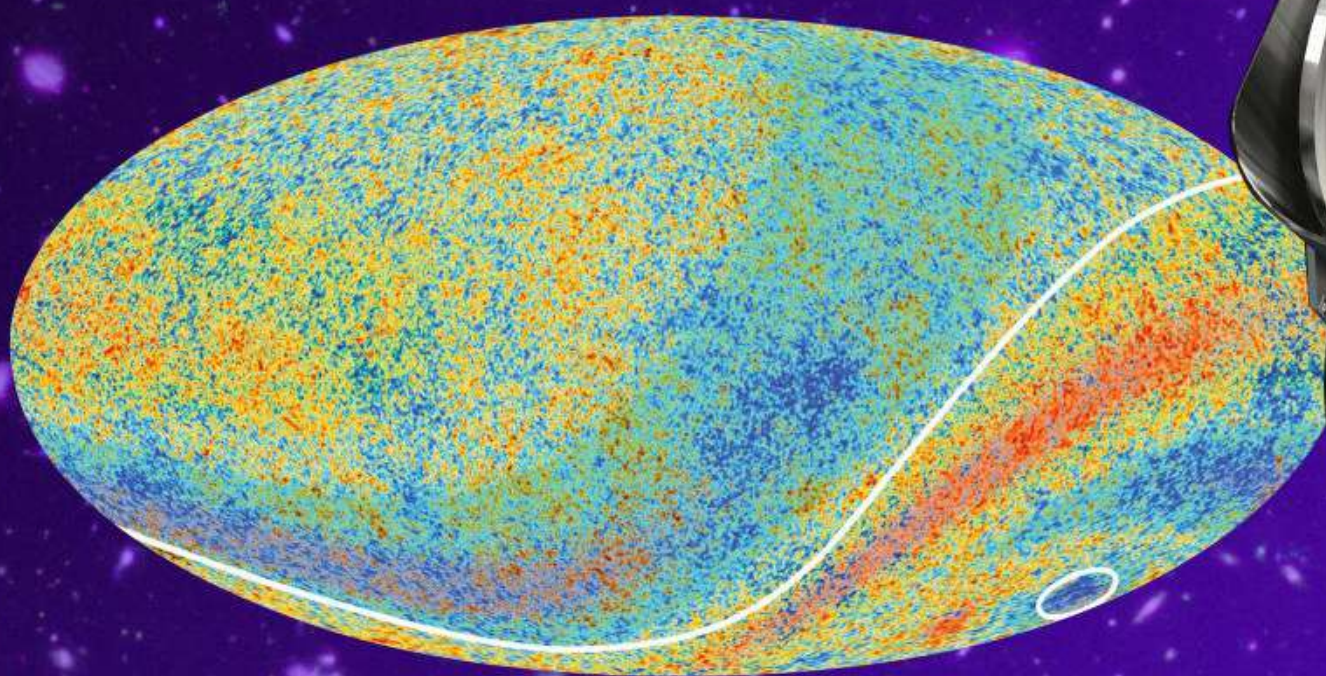




Left (clockwise): A timeline of the history of the universe, from the release of the CMB to the formation of the first stars and galaxies

This orbital outpost has provided our best map of the CMB

One cold spot in the CMB is ten times the size of the other cold spots



Bang started with a singularity," Poplawski says. A singularity is an infinitely small, infinitely heavy point. This point would have grown to the size of a marble during inflation and then carried on expanding. But the birth of our universe isn't the only place you encounter singularities. "The matter falling into a black hole also ends up at a singularity," explains Poplawski. Black holes are gravitational monsters from which nothing can escape if drawn in. He wondered whether that final singularity in a black hole might actually provide an initial singularity for a new universe.

The trouble with singularities is that an infinitely small, infinitely dense point makes no physical sense. How can something have no size or be infinitely heavy? So Poplawski hit upon a mechanism by which the matter falling into a black hole gets very close to forming a singularity - an incredibly small, incredibly dense point - but 'bounces' before it gets infinitely small and dense. But where does it bounce? Material can't bounce out of the black hole because by definition nothing can

"THERE IS NO EVIDENCE FOR AN EDGE TO THE UNIVERSE, BUT THERE IS AN EDGE TO WHAT WE CAN SEE" ANDREW PONTZEN

escape from its clutches. "It has to go somewhere," he says. "After the bounce it explodes and creates new space - a new universe." When explaining his idea to his students he uses an analogy based on the famous science-fiction series *Doctor Who*. "When you enter the TARDIS you realise you're in a space larger than a police box," he says. "Just as the TARDIS door is a door to a spacecraft, so a black hole is a spherical door to a new universe."

If Poplawski is right, our universe was created by a black hole in another universe. What does that mean for the edge of our universe? "It wouldn't have one," he says. "It would be like the surface of a sphere." The Earth's surface, for example, has no edge. If you were to walk out of your house and travel in a straight line, you would end up back

where you started. According to Poplawski's idea, if you travelled far enough away from Earth you would end up looping right the way back round and returning home. No edge, no boundary.

For now it is hard to know which of these pictures is the right one. It could be that the universe ends somewhere beyond our cosmic horizon. Or it could go on forever, meaning there are definitely copies of you out there in space. Equally, though, we could be nested inside one great multiverse, or the calamitous result of a black hole forming in another cosmos. Only further investigation, more observations and a higher volume of astronomical data will be able to tell us more. What is certain, however, is that there is more to this universe than meets the eye.

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ExoMars Trace Gas Orbiter

This member of the ExoMars team is a vital component in the hunt for methane in the Red Planet's atmosphere

Mission type

Orbiter

Operator

European Space Agency
and Roscosmos

Launch date

14 March 2016

Target

Mars

Arrival at target

19 October 2016

Primary objective

Analyse the trace gases in
Mars' atmosphere

Status

Operational



Håkan Svedhem Project scientist of the Trace Gas Orbiter

As the ExoMars mission is both a joint ESA and Roscosmos endeavour, they both have their own dedicated teams to understand the data collected by the TGO. For the ESA the project scientist is Swedish physicist Håkan Svedhem, who was also project scientist of the Venus Express mission.

ExoMars is a collaborative effort between the European Space Agency (ESA) and Russia's Roscosmos.

Launched in March 2016, the Trace Gas Orbiter (TGO) is part of the first instalment of an extensive exploratory mission, a venture that also includes the Rosalind Franklin rover, scheduled for touchdown on Mars in mid-2023. Accompanying the TGO was the descent module named Schiaparelli.

The TGO swung into Martian orbit on 19 October 2016 and, soon after arrival, Schiaparelli detached from the orbiter and began its journey to the surface. This module was created to demonstrate how a robotic lander could enter, descend and land on the surface of Mars. However, this demonstration was unsuccessful as conflicting information in the module's computer led to a crash landing. While Schiaparelli was demonstrating how not to land on the surface, the TGO was preparing itself for a new level of atmospheric analysis.

Before the orbiter could begin any in-depth scientific studies it had to calibrate its equipment. It then shifted itself into an orbit around Mars that would allow it to get up close. Next the orbiter tested its instruments and provided some amazing images of the Red Planet's surface, courtesy of the Colour and Stereo Surface Imaging System (CaSSIS). At the time the ESA's TGO project scientist, Håkan Svedhem, said: "This first impression provides a fantastic preview of what's to come when we start collecting data for real. Not only is the spacecraft itself clearly performing well, but I am delighted to see the teams working together so effectively."

The images and data returned from the initial instrument calibration excited astronomers back on Earth, but they had to wait until the spacecraft had gone from a extremely elliptical orbit - which took it

98,000 kilometres (61,000 miles) from the planet's surface - to a planet-hugging, circular orbit that had it hovering just 400 kilometres (250 miles) above the surface - a similar altitude to the International Space Station around Earth.

The technique used to alter the spacecraft's orbit is known as 'aerobraking'. It uses the planet's upper atmosphere to slow the spacecraft down and reduce the size of its orbit. This took around a year, and in-depth scientific investigation only truly began in April 2018. "Then the craft was reoriented to keep its camera pointing downwards and its spectrometers towards the Sun so as to observe the Mars atmosphere, and we could finally begin the long-awaited science phase," says Svedhem.

But what exactly is it looking for? If you've not gathered from the name already, the orbiter's primary objective is to build an inventory of the gases that make up less than one per cent of the Martian atmosphere by volume. These gases include water vapour, nitrogen oxides, acetylene and - most important of all - methane.

The planet's atmosphere is dominated by carbon dioxide, which constitutes a whopping 95 per cent of the atmosphere. This gas is deadly to us humans, but it is methane that scientists are more interested in, as it can be a calling card for biological activity. This short-lived compound is produced as a by-product of human life, but it can also be created in abiotic, chemical reactions. The issue is that so far no orbiter, rover or astronomer with a prying telescope can pin down the source of the methane, and henceforth cannot say with certainty that biological life of some sort is releasing this methane into the atmosphere.

"Just as the question of the presence of methane and where it might be coming from has caused so much debate, the issue of where it is going, and

ExoMars anatomy

High-gain antenna

The 2.2-metre (7.2-foot) parabolic antenna will provide consistent communication with Earth via the medium of X-band transponders.

FREND

The Fine-Resolution Epithermal Neutron Detector is capable of scratching the surface from orbit - it maps sources of hydrogen in the surface to a depth of a metre (3.2 feet). This will reveal any potential deposits of water ice.

CaSSIS

The Colour and Stereo Surface Imaging System is the main photography instrument, tasked with providing valuable geographical and dynamical context to other pieces of data.

Schiaparelli

This module was tasked with understanding the difficulties of accessing the Martian surface from space. With a rover due to arrive in 2023, Schiaparelli can be thought of as the warm up to the main event.

NOMAD

The Nadir and Occultation for Mars Discovery contains three spectrometers - two infrared and one ultraviolet - to gain precise measurements of the atmosphere's trace gases by aligning itself with direct sunlight, also known as solar occultation.

ACS

The Atmospheric Chemistry Suite will have three infrared spectrometers that also utilise solar occultation to categorise the chemistry of the atmosphere.

Solar Panels

When outstretched the solar panels measure 17.5 metres (57 feet) from tip to tip. They will on average generate 2,000 Watts of power.

how quickly it can disappear, is equally interesting," says Svedhem. "We don't have all the pieces of the puzzle or see the full picture yet, but that is why we are there with TGO, making a detailed analysis of the atmosphere with the best instruments we have to better understand how active this planet is - whether geologically or biologically."

The other duty of TGO is to act as a communications buffer between operations on the surface of Mars and the hardworking teams based on Earth. As part of a test run the orbiter was in constant communication with Schiaparelli as it made its descent to the surface, and it will again provide a communications relay between the Earth and the Rosalind Franklin rover when it reaches the Red Planet.

MISSION PROFILE

Progress report

In April 2019 the TGO completed its first year of full-time scientific observation, and astronomers couldn't be happier with what they saw, especially as they were able to exploit the rare opportunity of observing a global dust storm up close. "We are delighted with the first results from the Trace Gas Orbiter," says Svedhem. "Our instruments are performing extremely well and even within the first few months of observation were already providing exquisite data to a much higher level than previously achieved."

Using the onboard spectrometers astronomers were able to observe Mars' upper atmosphere as the dust storm enveloped the planet and observe how hydrogen was leaving the atmosphere.

However, Mars' methane - the main gas that the orbiter is trying to trace - appears even more mysterious after the annual announcement. The most accurate global analysis yet of the potential biosignature has shown the upper limit of methane's abundance in the atmosphere to be between 10 and 100 times lower than previous detections. This upper limit indicates that 500 tonnes of methane was emitted over a 300-year predicted lifetime of the molecule when considering

atmospheric destruction processes alone, which is considerably low.

In news much closer to the surface, the TGO data was pivotal in creating an incredible map of subsurface water, which could have interesting implications for understanding the ancient history of surface water on the Red Planet, as well as future human exploration and colonisation. The spacecraft's neutron detector - the Fine-Resolution Epithermal Neutron Detector (FREND) - has already produced one of the most exquisite maps of shallow, subsurface water ice and hydrated minerals in just one Earth year.

In the most recent news, it isn't just Earth where COVID-19 is having a negative effect, as in March 2020 the ESA decided to put four missions on temporary standby. These four were the TGO, the Solar Orbiter, Mars Express and the four-satellite Cluster mission. This was due to staffing restrictions during uncertain times, but they were woken back up on 2 April 2020 to resume usual service.



The potential production and distribution of methane on Mars

Methane-stuffed crust

Pockets of frozen methane could still exist from the planet's formation and ancient evolution. As the unfiltered solar rays crack the surface, these pockets could release spikes of methane.

Subsurface vents

If Mars' interior includes a liquid layer underneath the surface crust, then hydrothermal vents on the liquid layer's floor could be spraying out methane.

Miraculous microbes

This could be key in finding alien life. As we know, life produces methane, and the only life that could exist on Mars is in the form of subsurface microbial life.



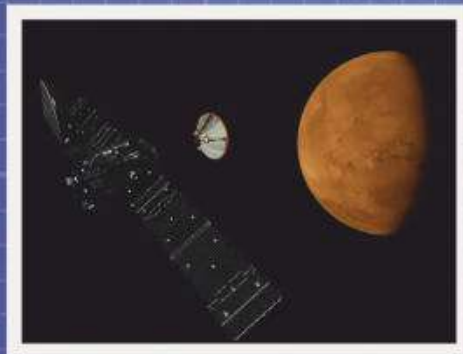
TGO pictured Korolev crater after shifting to its new orbit in April 2018

What happened to Schiaparelli?

Schiaparelli separates

16 October 2016 / 14:42:00

After a seven-month voyage through the Solar System the first instalment of the ExoMars package arrived at Mars. This started the separation of the orbiter and Schiaparelli.



Wake from hibernation

19 October 2016 / 13:29:48

Spacecraft tend to hibernate during their voyage in order to save power and maintain software. The ExoMars team awoke Schiaparelli after a further three-day journey.



Feel of the atmosphere

19 October 2016 / 14:42:22

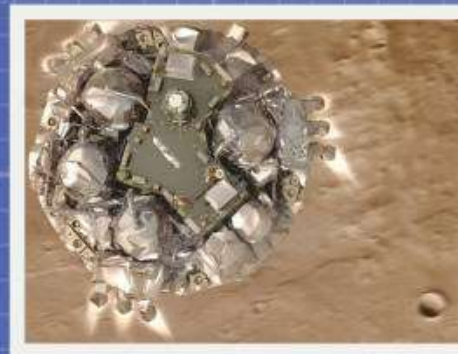
The entry, descent and landing demonstrator module's accelerometers first felt the touch of Mars' atmosphere just over an hour after waking up from hibernation.

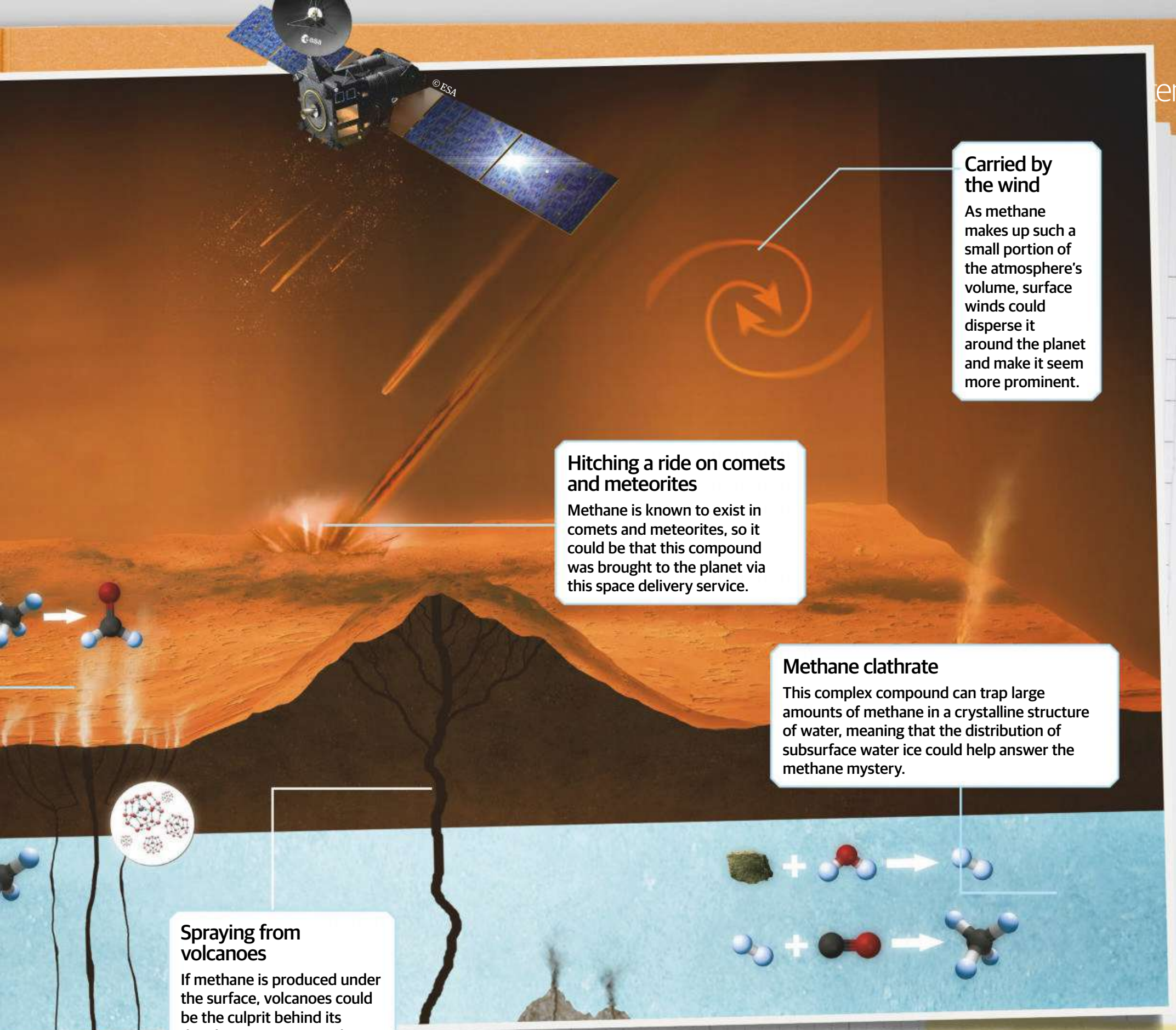


Data glitch

19 October 2016 / 14:45:23

Much of the time spent trying to slow the lander down went relatively smoothly, except when the lander began spinning unexpectedly about three minutes into the descent.





Carried by the wind

As methane makes up such a small portion of the atmosphere's volume, surface winds could disperse it around the planet and make it seem more prominent.

Hitching a ride on comets and meteorites

Methane is known to exist in comets and meteorites, so it could be that this compound was brought to the planet via this space delivery service.

Methane clathrate

This complex compound can trap large amounts of methane in a crystalline structure of water, meaning that the distribution of subsurface water ice could help answer the methane mystery.

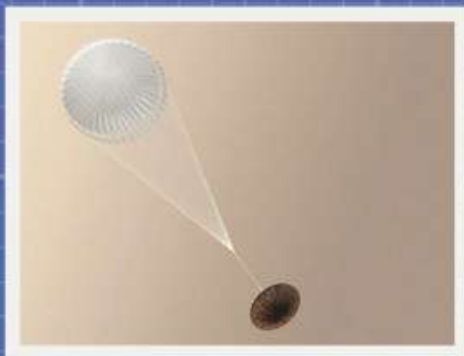
Spraying from volcanoes

If methane is produced under the surface, volcanoes could be the culprit behind its distribution. However, this is unlikely due to the planet's current prolonged stretch of inactivity.

Mistiming landing

19 October 2019 / 14:46:03

This glitch meant the spacecraft thought it was close to landing and consequently released its parachute, its back shell and briefly began firing its landing thrusters far too early.



Crash, bang, wallop

19 October 2016 / 14:47:28

The spacecraft fell from 3.7 kilometres (2.3 miles) altitude. The ExoMars team estimated that it impacted the ground at a speed of 540 kilometres (336 miles) per hour.



Found by a friend

1 November 2016

NASA's Mars Reconnaissance Orbiter took the first colour image of the Schiaparelli impact site, revealing how the debris was dispersed around the module.



Main objectives

Provide an inventory of the trace gases in Mars' atmosphere

The orbiter carries a scientific suite of spectrometers and cameras that are probing the Martian atmosphere and investigating the gases that make up less than one per cent of the total volume. The prime target of this investigation is methane, as its potential implication as a sign of biological life has teased astronomers for decades.

Provide important data relay between surface operations and Earth

The ExoMars mission will not only investigate the planet from orbit, but also on the surface. The TGO will also serve as a vital orbital outpost, previously relaying data as the Schiaparelli demonstrator descended through the atmosphere. In the future it will relay information collected by the Rosalind Franklin rover.

SPACE, SATELLITES AND SELF-ISOLATION

THE ASTRONOMICAL IMPACT OF COVID-19

Coronavirus has had seismic effects on all aspects of life globally, but what has the space industry been able to tell us, and what can it do to help?

Reported by Lee Cavendish

FIVE WAYS TO PASS THE TIME IN ISOLATION

1

NASA at Home

On the NASA homepage - [nasa.gov](https://www.nasa.gov) - the US space agency has set up its #NASAatHome activities page. This new and interactive subsection of the NASA website offers a range of offerings to engage the whole family. There are podcasts, videos, projects and even virtual- and augmented-reality tours that will bring the universe to anyone's home.



The world is in the midst of an unprecedented pandemic, and it is having a profound effect on individuals, businesses and industries across the globe. Since COVID-19 - also known as 'coronavirus' - gained global attention at the beginning of 2020, it has had a knock-on effect that can even be seen from space.

In response to battling the virus, almost all the world's governments have issued strict lockdown policies stating that people can only leave their homes for essential shopping and going to work - but only for key workers. This has led to a dramatic reduction in travel, with local non-essential businesses being asked to close their doors temporarily and public gatherings being postponed.

The harmful emissions that usually permeate the atmosphere above busy cities are now drastically clearing as a consequence of these closures. Although COVID-19 is a negative situation as a whole, the side effects it's having on the planet's atmosphere and the environment are a minor positive. Calls for a large-scale reduction of fossil-fuel burning and other means of harmful emission production have intensified over the last few years, and in the midst of this pandemic satellites in low-Earth orbit have been able to see what fossil-fuel abstinence can do for our planet.

The European Space Agency (ESA) has a fleet of satellites dedicated to observing Earth from space and noting any changes that occur. This all falls under the space agency's Copernicus Programme. Named after the famous Polish astronomer who first suggested that Earth revolves around the Sun, this satellite suite namesake was created to manage the environment and understand the influence of climate change. One particular member of the Copernicus family, known as a Sentinel, has been observing the concentration of nitrogen dioxide over the globe, which is directly linked to the severity of air pollution.

Wuhan, a city in the Chinese province of Hubei, is largely regarded as the global epicentre of the COVID-19 outbreak, meaning that China was the first country to exhibit strict lockdown protocols. Over the course of December 2019 and January, February and March 2020, the Copernicus Sentinel-5P satellite provided timely updates on the concentration of nitrogen dioxide, which is usually released via power plants, vehicles and industrial facilities. When the team put together images taken over the course of three months, a dramatic reduction in the molecule's concentration over the entire country was shown, most noticeably above Beijing and Shanghai. These two cities are almost synonymous with air pollution and bad air quality. They are hugely populated cities in a country where it was reported in 2012 that air pollution was responsible for over a million deaths. To have a drastic drop in these emissions could actually save

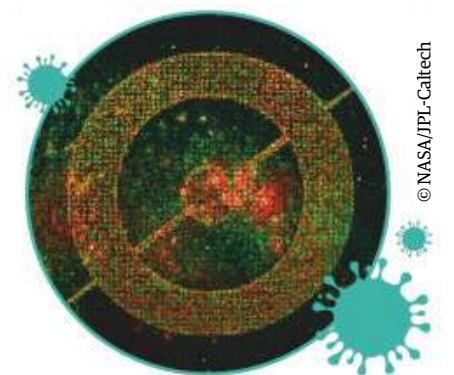


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The Zooniverse

Citizen science is a popular way to contribute to real science projects from the comfort of your own home. All you need is a laptop or computer with an internet connection and you can do some 'real science'. The Zooniverse, found at [zooniverse.org](https://www.zooniverse.org), is a world-famous organisation that contributes to hundreds of scientific projects and thrives on citizen science. If you want to help contribute by finding asteroids, exoplanets or even penguins, the Zooniverse is the place to be.



© NASA/JPL-Caltech

Above: NASA can't risk sending all workers home as astronauts aboard the ISS rely upon constant communication

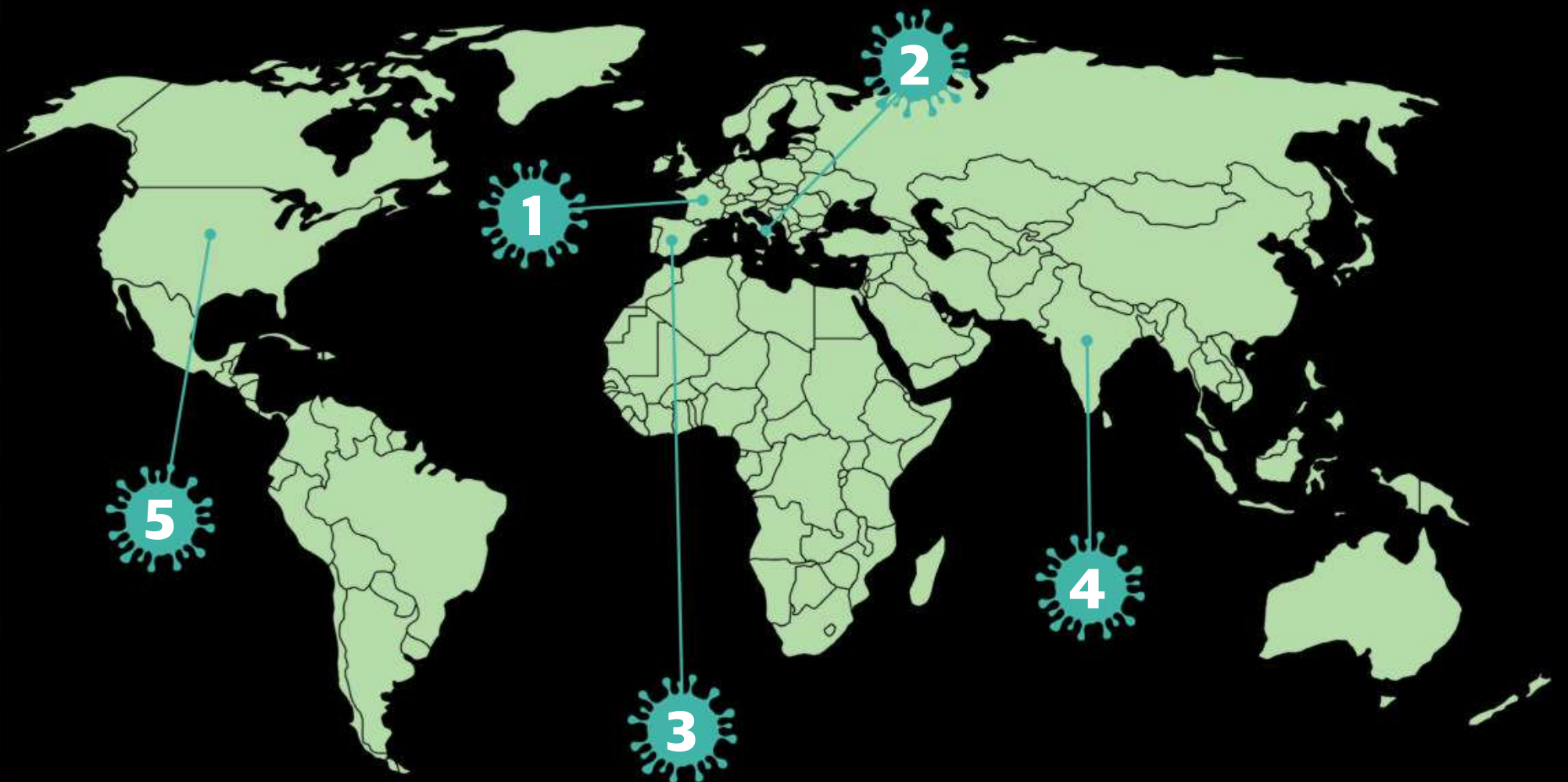
Right: Peggy Whitson (left) and Thomas Pesquet (right) were both on the ISS for Expeditions 50 and 51



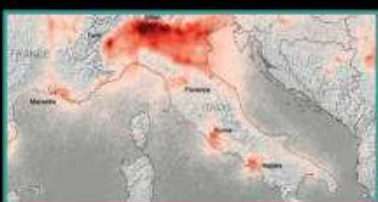
© NASA

BEFORE AND AFTER: AIR-POLLUTANT LEVELS AFTER ISOLATION

These images, courtesy of ESA's Copernicus Programme and NASA's Aura satellite, show the drastic improvement in air quality as a consequence of a global lockdown



Before



1. France

The majority of France doesn't usually experience high levels of nitrogen dioxide in its atmosphere, the expected exceptions being Paris, Lyon, Marseille and Lille. Paris has experienced an approximate 54 per cent drop in air pollutants compared to previous years.

2. Italy

Italy was the first country in Europe to be hit hard by coronavirus, with a lockdown put into place in response to try and slow the spread. The northern region is normally heavily polluted, as shown in the large dark-red patches. In March 2020 Milan showed an approximate 47 per cent drop.

3. Spain

Spain was arguably the second country in Europe to feel the worst effects of the virus, and as a result was put under extremely intense lockdown conditions. This lockdown has led to a 48 per cent reduction in air pollutants in the Spanish capital of Madrid.

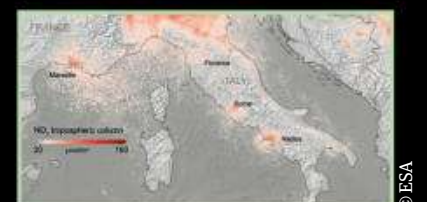
4. India

After the Indian government put over a billion people in lockdown in late-March, the country has experienced a dramatic and rapid reduction in nitrogen dioxide. In fact, compared to the average levels of January to March 2020, cities such as Mumbai and Delhi have experienced a drop of between 40 and 50 per cent.

5. United States

The United States' northeastern coast houses some of its busiest cities, such as New York, Boston, Philadelphia and Washington, D.C.. The average nitrogen dioxide emission from March 2015 to 2019 has been very high. As expected, measurements from March 2020 have shown a massive 30 per cent reduction.

After



SENTINEL FAMILY

The ESA's Sentinels are designated to Earth observation, but each offers a unique function

Sentinel-1 25 April 2016

Radar imager for land and ocean services.

Sentinel-2 7 March 2017

Monitors vegetation, soil and water cover, inland waterways and coastal areas.

Sentinel-3 16 February 2016

It measures sea-surface topography as well as surface temperature and colour.

Sentinel-4 2023

Dedicated to monitoring atmospheric composition.

Sentinel-5 2021

Also designed to measure atmospheric composition, but from a polar orbit.

Sentinel-5P 13 October 2017

Measures the concentrations of trace gases, such as nitrogen dioxide, and aerosols in Earth's atmosphere.

Sentinel-6 2026

Intended to measure global sea-surface height using its radar altimeter for oceanography and climate studies.



Night-sky observing

An age-old activity that was around way before any computer, gaming console or motor vehicle is classic night-sky observing. This can be done in the confines of your back garden, a local field or just about anywhere you can safely gain access to patches of dark sky away from light pollution. This can provide the opportunity to study planets, learn constellations and try and spot the International Space Station as it orbits above. You could even crack out a telescope for a more in-depth observation!



Venice, Turin and others are thought of as the economical heart of the country, so to have such firm restrictions in place obviously took its toll. However, these restrictions consequently saw a reduction in nitrogen dioxide. Not only that but the waters of Venice appear to be returning to their former unpolluted beauty.

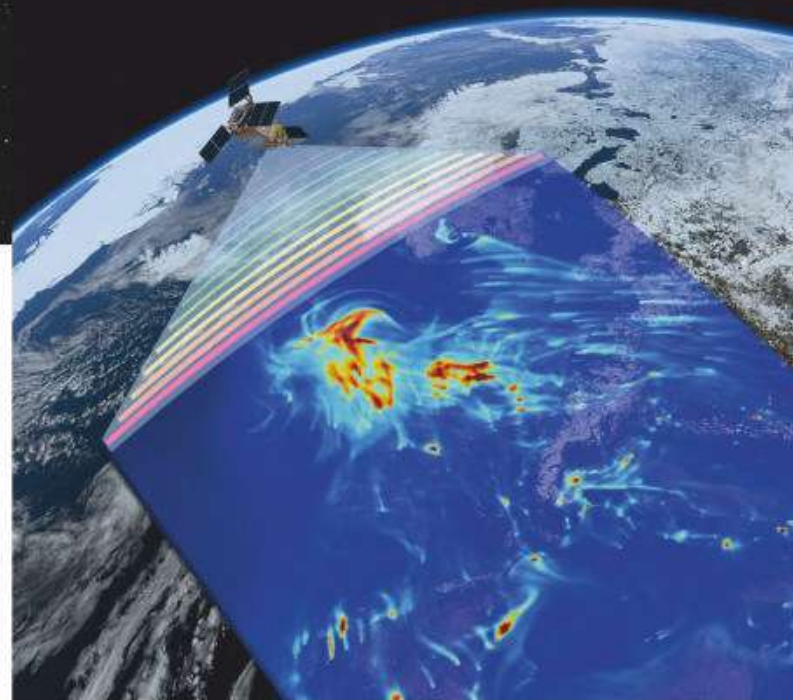
Venice, 'the floating city', is a beautiful place to visit, but because of this it's a tourist hotbed. Tourist demand in recent years has led to more boat traffic and pollutants being released into the city's majestic canals. Another member of the Copernicus Programme, Sentinel-2, revealed the difference in water quality between 13 April 2019 and 19 April 2020, and the contrast is incredible. The obvious murky discharge from overtourism has faded. The waters appear clearer, and nature is returning.

At the time of writing the latest results from the Copernicus Programme show that four major European cities - Milan, Rome, Paris and Madrid - all exhibit much less air-pollutant concentrations compared to the previous year. Decreases average out to 50 per cent less than the previous year, with Paris showing the greatest reduction with 54 per

Right:
Sentinel-5P
has delivered
valuable high-
precision data
about Earth's
atmosphere

cent. However, this is still scientific observation, and uncertainty needs to be taken into account - to the tune of 15 per cent for these calculations. Nevertheless, the lowest average is still a 35 per cent reduction of air pollutants, which is an incredible feat for humankind in some of the most industrially demanding cities of the world.

NASA also has its own set of eyes from above, with satellites that contribute to the space agency's Earth Observing System (EOS). The two satellites in focus, Aura and Terra, have likewise been monitoring air pollution in the form of nitrogen dioxide and aerosols respectively. The results from the Aura satellite show that the northeastern



4

Catch up on some reading

While isolated and with plenty of time on your hands, this could be the perfect chance to read some of the books you have collecting dust on your shelves. With the recent Apollo anniversaries, there are some great books out there telling the stories of those missions. There is an array of fascinating and informative astronomy and space-related books just waiting to be ordered.



region of the US had a 30 per cent lower average concentration of nitrogen dioxide when compared to the averages in March 2015 to 2019. Its partner, Terra, has been keeping an eye on India since the strict lockdown of 1.3 billion people on 25 March 2020. Remarkably, in less than a month's time NASA's satellite had measured a 20-year record low in aerosol levels over the country.

While space agencies continue to carefully monitor the data collected by these Earth-observing satellites, the same agencies have had to carefully manage the operations of space science probes elsewhere in the Solar System. NASA, the ESA and other space agencies have not been exempt from the stern recommendations to work from

home where possible. As staff cannot take a whole command centre home to operate a spacecraft on another planet, a few missions have had to be put into hibernation due to these staff restrictions and work from home orders.

On 25 March 2020 the ESA made the decision to put four of its missions on 'temporary standby' - thus suspending all scientific operations - due to staffing restrictions at the European Space Operations Centre (ESOC) in Darmstadt, Germany. The four-satellite Cluster mission, the ExoMars Trace Gas Orbiter, the Mars Express orbiter and the recently launched Solar Orbiter had their scientific operations suspended until 5 April. Although this was a short period of time, it still demonstrates the gravity of the situation and the extent to which space agencies are going to prioritise the health of staff. The highly anticipated Rosalind Franklin rover, which is the next instalment in the European and Russian Martian astrobiology mission, has had its launch pushed back until 2022, but this was due more to technical difficulties as opposed to a COVID-related knock-on effect.

NASA had a big scare back on 23 March when an employee from NASA's Kennedy Space Center in Florida tested positive for coronavirus. However, three days prior to this announcement NASA issued a statement outlining that employees will be working from home unless absolutely necessary and will continue to support mission-essential operations for all spacecraft. However, this has meant that projects in the pipeline - such as the James Webb Space Telescope, the Space Launch System rocket and Orion spacecraft - have had their production and testing temporarily suspended. NASA has continued with the production of its Mars 2020 mission, as it is a high priority to the agency. This means that the space agency still intends to launch the Perseverance rover and Mars Helicopter in July or August of this year ahead of its intended



Above: NASA is still planning on launching its Mars 2020 mission in July or August of this year

Right: The Main Control Room at the ESA's Space Operations Centre communicates with spacecraft throughout the Solar System

arrival next year in February 2021.

Meanwhile, as space agencies across the world look to juggle their obligations to build, launch and maintain spacecraft with minimal in-situ staff, they are continuing business on board the International Space Station (ISS) as normal. Although there are precautions in place to make sure the virus does not find its way onto the station, the astronaut launches and returns are happening as originally planned, with no delays.

In this current and uncertain climate, astronauts can provide a service that is just as valuable as the work they do in low-Earth orbit. In fact, if there is a group of people who know how to be confined in a small space for months on end, away from their loved ones, it's astronauts. Because of this expertise with isolation, astronauts have been explaining how quarantining with your family echoes living on the ISS and have been sharing what tips they have for people who are struggling.

In an interview with the United States news show *CBS This Morning*, retired NASA astronaut Peggy Whitson - who in 2017 broke the record for most cumulative days in space with a whopping total of 665 days, 22 hours and 22 minutes - spoke about effective communication. "[Self-isolation is] actually

"THE REDUCTION IN CONCENTRATION COINCIDES WITH THE LOCKDOWN CAUSING LESS TRAFFIC AND INDUSTRIAL ACTIVITIES"

CLAUS ZEHNER



Astronaut workout

Maintaining physical fitness should be taken very seriously. It is easy to fall into a pit of mooching around, and this can have damaging effects on your physical and mental wellbeing. Luckily astronauts are experts on working out in small spaces, and many of them have offered their experience to the public. All it takes is a quick Google and you can have the help of an astronaut when it comes to creating an isolation workout that will help keep you healthy.

very doable, but it's very important to be able to interact well with the people you're staying with, living with."

The ESA also released a video in March 2020 with French astronaut Thomas Pesquet's tips for social distancing. As a bit of light-hearted fun, he suggested keeping yourself occupied with tasks such as going through old photos taken on the ISS, reading some of the classics and sleeping in a vertical sleeping bag suspended from the coat hook of a door. In all seriousness, however, Pesquet stated that there are three key points to remember during this COVID-19 outbreak. Firstly, always listen to the instructions of the government and health professionals. Secondly, wash your hands and do so consistently. Finally - and with the most emphasis of all - stay at home.



Below:
NASA has an incredible fleet of satellites for monitoring environmental changes on Earth



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CREW DRAGON LAUNCH

This spring will see the return of astronauts being launched from American soil aboard SpaceX's Crew Dragon capsule

Reported by Lee Cavendish

The last time the US launched astronauts from American soil on a homemade spacecraft was the final mission of NASA's Space Shuttle program, STS-135, on 8 July 2011. After 135 missions the program was brought to a close, and NASA instead began launching astronauts from the Baikonur Cosmodrome in Kazakhstan aboard Russian Soyuz rockets.

Fast forward to 2020 and the space agency is preparing for a historic test flight as part of its Commercial Crew Program. This will eventually see SpaceX and Boeing become the US' main transportation providers between the International Space Station (ISS) and Earth, and the next major step will occur on 27 May 2020. On this day, two NASA astronauts – Bob Behnken and Doug Hurley – will journey to the ISS aboard SpaceX's Crew Dragon spacecraft in the first crewed test mission, designated 'Demo-2'.

The launch will take place at approximately 21:32 BST (16:32 EDT) from the Kennedy Space Center in Florida, the same site that initiated multiple Apollo and Space Shuttle missions. As the torch is handed over to SpaceX, this is not just a huge step in returning operations to the US in a grand patriotic fashion, but represents the trust shown between space agencies and private aerospace companies and how the relationship has developed over the last decade.

SpaceX is a great example of this. Over the years, the company has gained the confidence of NASA to not only be trusted with resupply missions to the ISS, but is now delivering astronauts to the Space Station. These partnerships prove to a new

generation that space is more accessible now than it ever has been.

The first test mission, dubbed Demo-1, was conducted on 2 March 2019 and saw the empty Crew Dragon capsule delivered to the ISS, returning back to Earth with a splash six days later. Around a month after the test, the same capsule was destroyed in an explosion caused by the thrusters during further testing. This explosion pushed back the manned launch as the aerospace company looked to get to the bottom of the problem to ensure that the same thing will not occur with passengers on board.

In January 2020 SpaceX ached an abort test that saw a Falcon 9 rocket explode intentionally to prove that the Crew Dragon capsule can evade such a dangerous situation and return the astronauts safely to Earth. This was monumental in the aim of regaining confidence in the capsule, and as a result, the launch date of 23 May has been designated for the next stage in evolving this important step in commercial spaceflight.



Below: Bob Behnken (left) and Doug Hurley (right) are pictured rehearsing the Demo-2 mission

“THESE PARTNERSHIPS PROVE TO A
NEW GENERATION THAT SPACE IS
MORE ACCESSIBLE NOW THAN IT
EVER HAS BEEN”

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WORKS**

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FEATURES

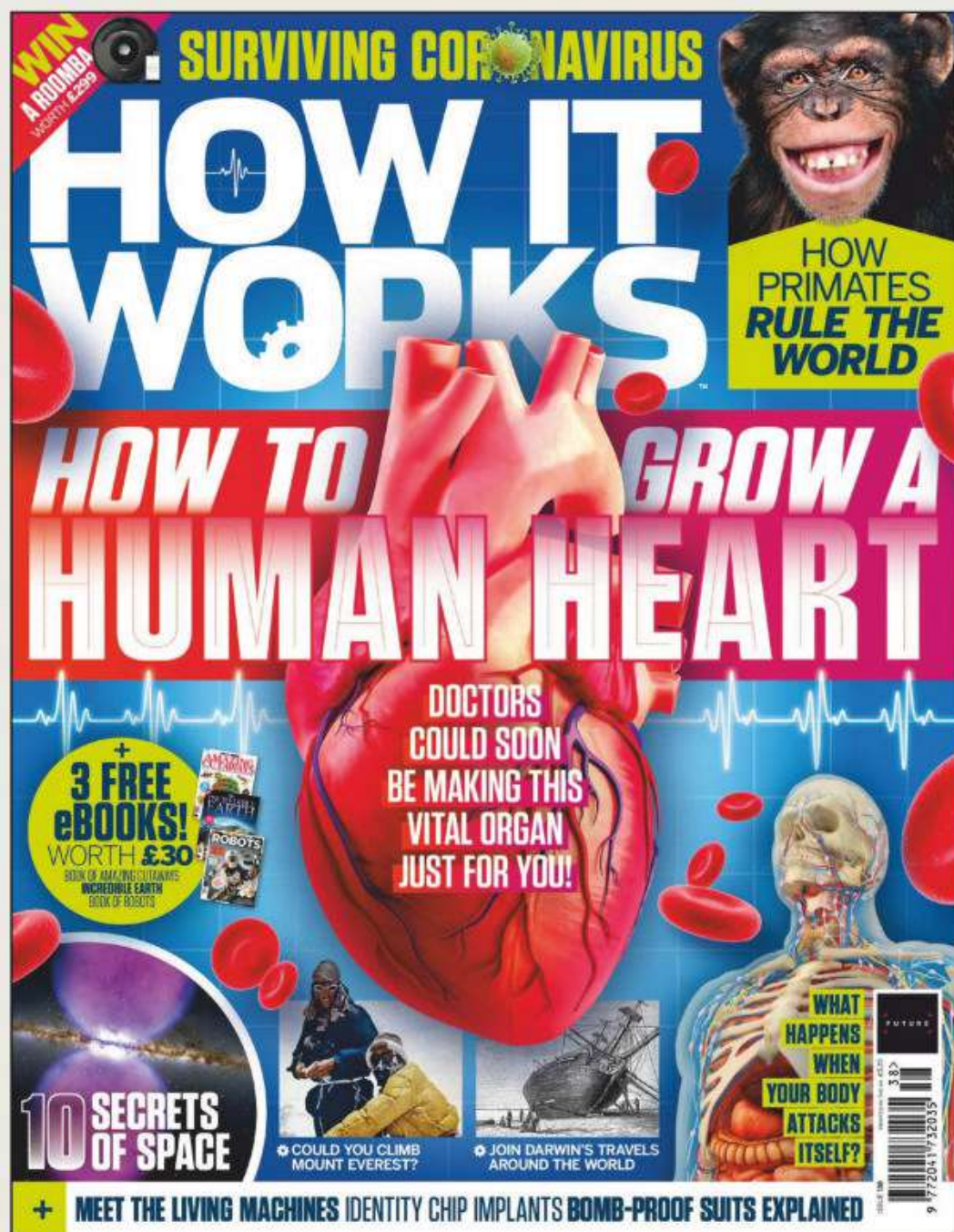
The speaker is made from solid metal. It features 3.5mm line-in connectivity and a playtime of six hours.

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HOW IT
WORKS

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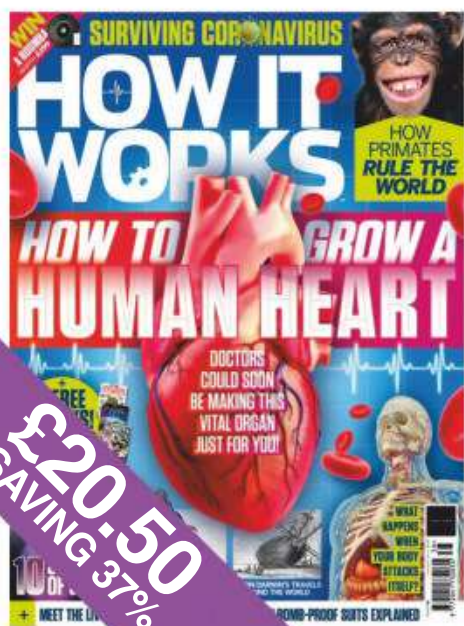
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EXOPLANETS

What do we know about Kepler-452b's surface?

We know very little about what the planet is like. We know that the star is essentially the same temperature as the Sun, about 5,500 degrees Celsius (9,900 degrees Fahrenheit), and is just a little bit bigger than the Sun. Its estimated age is 6 billion years old, so it's about 2 billion years older than our own star. We know that this planet is about five per cent farther from its star than our planet is from the Sun. That's what makes it very interesting: it's the closest analogue we have to the Sun-Earth system outside our own Solar System.

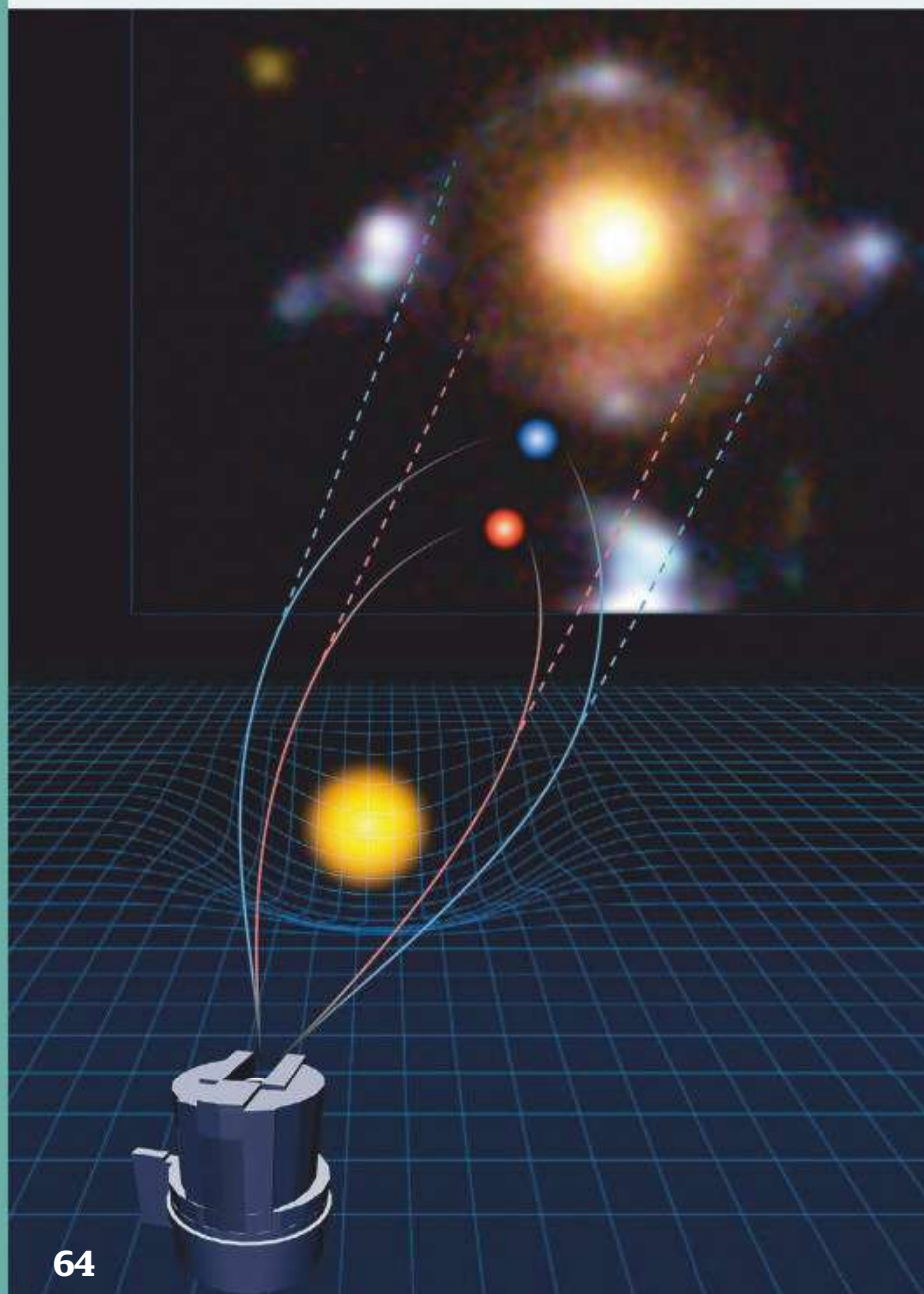
In terms of the surface of the planet, we don't have a mass measurement, so all we have to go on to understand whether this planet is likely to be rocky or not is to look at the populations of other exoplanets we have found.

It's kind of like looking at a classroom of children and measuring their heights and their weights, then the next day Sally comes to school but the balance is broken, so we can't measure her weight. However, we can still measure her height and then predict her weight based on the weights of the other students we measured. The same thing is true here - we measure the size of this planet and compare it against the sizes of other exoplanets for which we do have better measurements. Our best guess at this planet is about five times the mass of Earth, and there's a 50 to 60 per cent chance that it's rocky.



Jon Jenkins is a co-investigator for data processing on the Kepler and TESS missions at NASA's Ames Research Center

© NASA/JPL-Caltech Headshot © Seth Shostak/SETI Institute



Left: Enormous structures throughout the universe bend the paths of light rays

ASTROPHYSICS

Has there ever been an instance of double gravitational lensing?

Yes, assuming that you mean an instance where there are two galaxies at different redshifts acting as a lens, or two sources at different redshifts being lensed by the same foreground galaxy. In order to have a double ring you need to have an extraordinary coincidence of three objects aligned along the line of sight, and this is very rare. The first instance was discovered in 2008 by Raphael Gavazzi and myself as part of the SLACS Survey.

A few other cases have been found since. These few examples have been used to study the distribution of matter inside galaxies but also to learn about the composition of the universe in terms of dark matter and dark energy because the double gravitational lens geometry allows you to measure ratios of distances in the universe.

If you have a concentration of mass, it produces a perturbation of space-time. If there is a big mass it bends the trajectory of light rays, so we see light rays curving. If you have enough mass, light rays can curve and turn around the mass so you see more than one image of the system. From those ratios of distances you can infer how distances change over cosmic time, which in turn constrains the expansion history of the universe, and ultimately its contents.



Tommaso Treu is a professor of physics and astronomy at the University of California, Los Angeles (UCLA)

© NAOJ

Below: Kepler-452b was the first Earth-like exoplanet discovered in the habitable zone of a star like our Sun

Did you know?

The closest exoplanet to Earth discovered is Proxima Centauri b, which orbits a red dwarf host star just 4.2 light years from us.

"Can we build something that will be sensitive to gravitational waves?"

Paul McNamara

SPACE EXPLORATION

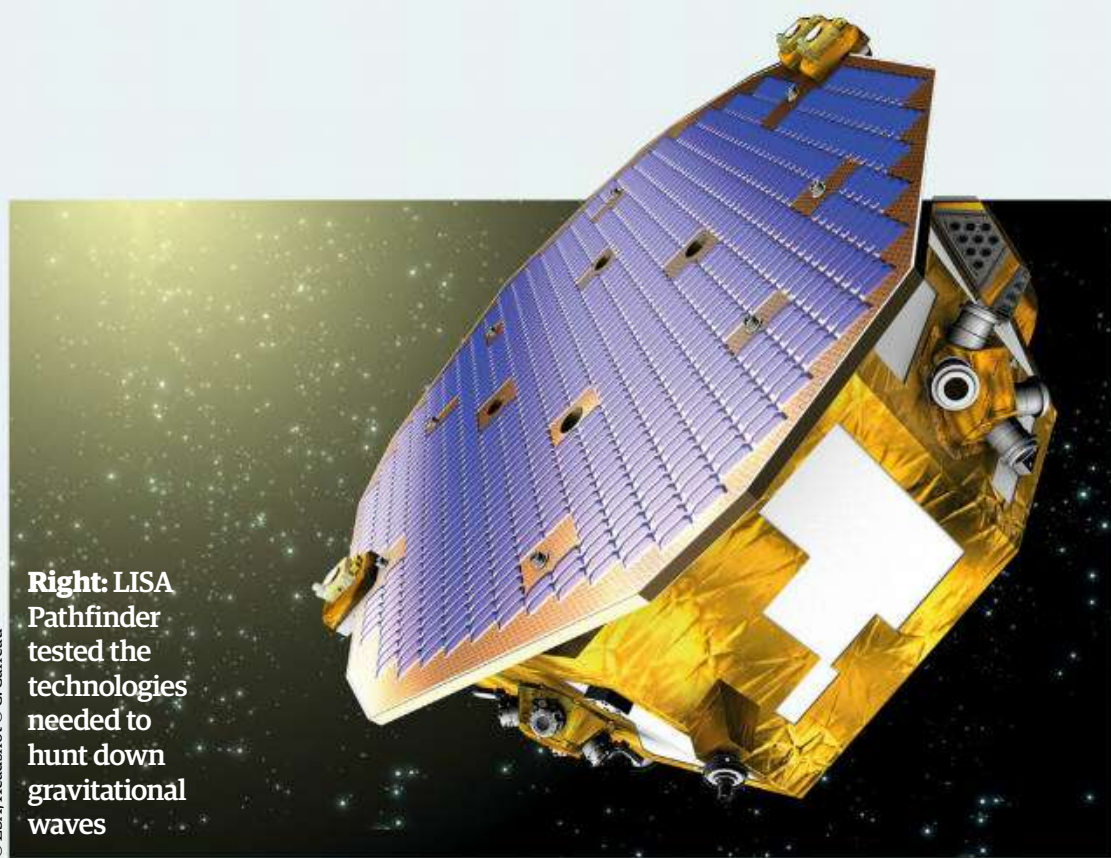
How did LISA Pathfinder work?

With LISA (Laser Interferometer Space Antenna) Pathfinder, effectively it was one 'arm' of a very small interferometer complete with two test masses and a laser. What we tested was whether we can make a measurement in the first place - can we build something that will be sensitive to gravitational waves when we build the larger version of it? To actually measure gravitational waves, you'd need two separate arms. You're essentially counting the 'ticks' of a laser light going along two different arms, and because you've got two arms you can cancel out a lot of the laser noise to make accurate measurements. But our arm was just way too short - we really need them to be more than a million kilometres (621,370 miles) long.

A significant issue with Pathfinder was that our two test masses lay on the same line - if our primary test mass started to drift towards one side then the whole spacecraft followed. The other test mass could hit the wall, and then it would no longer be free as it's in contact with the spacecraft. We had to constantly apply forces to the second test mass to make sure that didn't happen, and it's the force we had to apply to that second mass that's our primary science output. That's simply not an issue with the full LISA configuration: two test masses are floating in different spacecraft, so they can be allowed to drift in whatever direction they want.



Paul McNamara is project scientist for the LISA Pathfinder mission



Right: LISA Pathfinder tested the technologies needed to hunt down gravitational waves

TECHNOLOGY

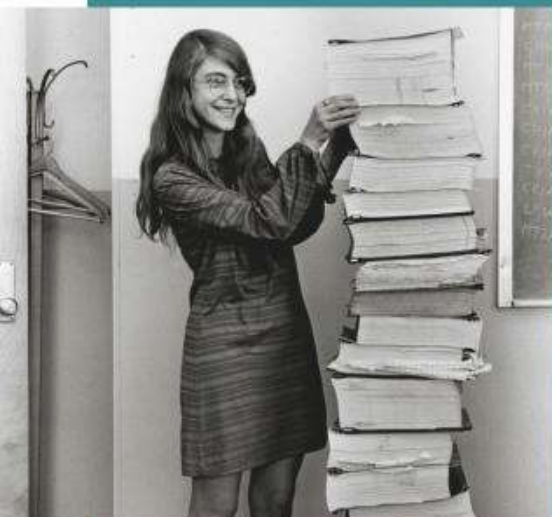
Are software engineering processes better now compared to the Apollo era?

Yes and no. We did a lot of research along the way based on lessons learned starting even before Apollo. What became clear was that they use the traditional life cycle, even back in those days, and they would always keep saying, "It's the nature of software. There's always going to be a problem." There's no way to solve it except to test things. You create errors when you put the code in, and you take it out and put patches in and you test - it's a very expensive process.

When you ask people today who are building software, they have the same problems as 50 years ago, and they give the same reason: it's the nature of software. It's just the way it is.

We learned along the way there was a better way to do things where you wouldn't have these issues. But we realise what is needed is education and the software engineers being willing to completely change the way they do things. Maybe it's going to happen, but it will still take time.

Margaret Hamilton is a computer scientist that helped develop the computer software for NASA's Apollo spacecraft



Left: Hamilton standing next to the coding that would take the first humans to the surface of the Moon

Right: The Fermi bubbles were observed in X-rays (blue) and gamma rays (purple)

ASTROPHYSICS

Can Fermi bubbles be produced in non-spiral galaxies?

We don't know the answer because we don't know with certainty the origin of the Fermi bubbles seen in our own galaxy. The Fermi bubbles are bilobular structures that emerge north and south from the galactic plane in the vicinity of the galactic nucleus. The original discoverers of the bubbles - and many other astrophysicists since - have favoured an interpretation that the bubbles are manifestations of a previous period of activity. This could have occurred something like a few million years ago. External galaxies which host flaring supermassive black holes are known as active galactic nuclei (AGN).

Other researchers have promoted the idea that the bubbles are signatures of the intense star formation that occurs around the supermassive black hole in the galaxy's Central Molecular Zone, or CMZ. This is a region only 0.01 per cent the area of the galaxy's disc that hosts about ten per cent of the molecular hydrogen - and a similar

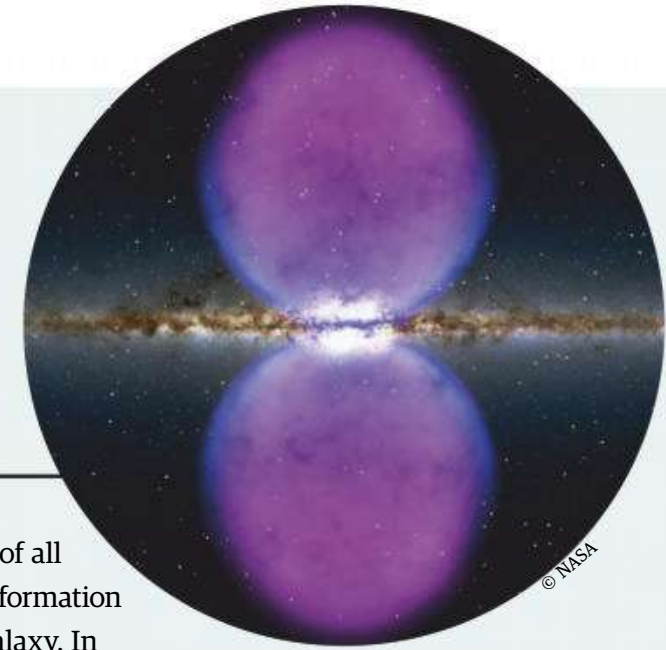
fraction of all the star formation in the galaxy. In

this scenario the bubbles are inflated much more slowly and gently by this sustained but intense star formation than in the AGN scenario.

If the Fermi bubbles were manifestations of a recent AGN phase in the Milky Way, then we might expect them in elliptical galaxies, which tend to host the universe's largest black holes and create giant radio- and gamma-ray-emitting lobes on larger scales than the Fermi bubbles. On the other hand, if the bubbles are energised by CMZ star formation then we would really only expect their exact analogues in spiral galaxies, because these are the only galaxies in the local cosmos that host sufficiently intense star formation.



Roland Crocker is an associate professor at the Australian National University, Canberra



SOLAR SYSTEM

How are objects temporarily captured into Earth's orbit?

There is a region around every planetary body in which the gravity of the body is stronger than that of other nearby bodies: the Hill sphere. If a near-Earth object that has a high velocity relative to Earth enters this region, it will pass by us with its trajectory slightly modified and continue in a heliocentric orbit. If an object enters the Hill sphere of Earth with the right velocity and angle, it can become a temporary satellite. The Earth-Moon system is

very stable. When you introduce a third body into the equation - like an approaching small asteroid - its orbit is very chaotic, hence it is extremely unlikely for these bodies to remain on a stable orbit around Earth.

Two probable natural objects have been observed to be in Earth's orbit. These are 2006 RH120 and the recently discovered 2020 CD3. It has been proposed that a larger population of temporary satellites exists, but they are small and faint, which means that they are difficult to detect. It is likely that we will have a better understanding of Earth's immediate surroundings and discover more of these temporary satellites once the Vera C. Rubin Observatory becomes operational.

Below: With the number of near-Earth objects, it could be that Earth has many mini-moons that aren't visible



Kacper Wierzechos is a senior research specialist at the University of Arizona



STARS

How would a coronal mass ejection (CME) affect the ISS?

Today we have several satellites that monitor the Sun and the local space environment, so we would have warning if a CME occurred to prepare ourselves both on Earth and on the International Space Station (ISS). Sometimes CMEs can cause 'solar particle events' where energetic protons and other nuclei are emitted by the Sun. Energetic particle irradiation may cause electronic errors, so during the CME event the ISS could choose to be electronically quiet to avoid computer glitches. Fortunately the electronics on spacecraft are designed to withstand particle irradiation. The silicon-cell solar panels of the ISS are glass-coated and would probably survive unscathed.

Most of the harmful radiation that astronauts on the ISS experience is from the higher energy

but less abundant galactic cosmic rays and the Van Allen belts of trapped particles. In a large solar particle event, astronauts can receive a significant dose of radiation from these high-energy protons over a few days.

A superstorm-like CME event may have another effect. X-rays from the event may deposit enough energy in Earth's atmosphere for it to expand. This would cause increased drag on satellites orbiting below about 600 kilometres (370 miles). The ISS orbits at roughly 400 kilometres (250 miles) altitude. The ISS uses rockets from attached spacecraft periodically to boost its orbit, so it may need an extra boost.

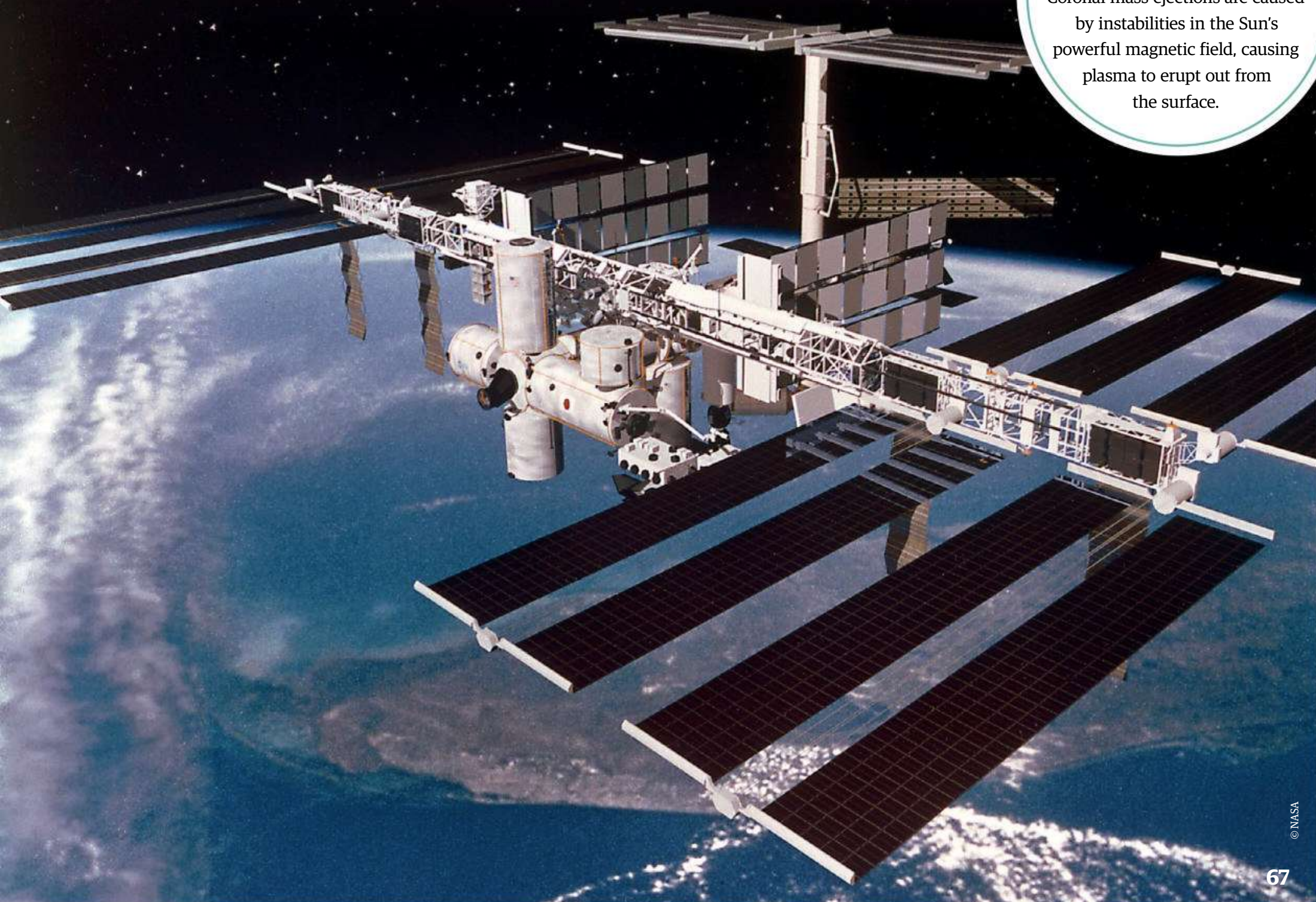


Ryan Ogliore is assistant professor of physics at Washington University in St. Louis, Missouri

Below: The ISS has accommodated up to six astronauts for over 20 years

Did you know?

Coronal mass ejections are caused by instabilities in the Sun's powerful magnetic field, causing plasma to erupt out from the surface.





STARGAZER

ESSENTIAL GUIDES AND ADVICE FOR AMATEUR ASTRONOMERS

In this issue...

68 What's in the sky?

You might have to stay up a little later, but the heavens are full of fantastic features

72 Month's planets

Jupiter is not only the king of the Solar System, but the ruler of the dawn sky

74 Moon tour

Find one of the most famous craters on the lunar surface, a science-fiction star

75 Naked eye and binocular targets

Use the tail of the Big Dipper as your guide

76 Deep sky challenge

June nights are perfect for exploring the hidden treasures of Ursa Major

78 The Northern Hemisphere

Late-night astronomers are treated to a stunning selection

80 Telescope review

Is the Celestron CPC 800 GPS (XLT) the right telescope for you?

What's in the sky?

**18
MAY**



Jupiter and Saturn make a close approach in Sagittarius and Capricornus

**29
MAY**



Mercury reaches half phase (dichotomy) in the evening sky, shining brightly at -0.1

**31
MAY**



Comet C/2019 Y4 (ATLAS) will make its closest approach to the Sun



© NASA, ESA & Hubble

**1
JUNE**



The Hercules Globular Cluster (Messier 13) is well placed for observation at +5.8



© NASA, ESA & Hubble

**8
JUNE**



Conjunction between the Moon and Jupiter in Sagittarius

**8
JUNE**



The Moon and Jupiter make a close approach, passing within 2°10' of each other

**9
JUNE**



Conjunction between the Moon and Saturn in Capricornus



© NASA, ESA & Hubble

**10
JUNE**



Globular cluster Messier 92 is well placed for observation in Hercules, glowing at +6.5

**12
JUNE**



Conjunction between Mars and Neptune in Aquarius



Jargon buster

Conjunction

A conjunction is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Right Ascension (RA)

Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

Declination (Dec)

This tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

Magnitude

An object's magnitude tells you how bright it appears from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object. So, a magnitude of -1 is brighter than an object with a magnitude of +2.

Opposition

When a celestial body is in line with the Earth and Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Greatest elongation

When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongations and as morning stars during western elongations.

Red light friendly
In order to preserve your night vision, you should read our observing guide under red light



**31
MAY**



Mercury reaches its highest point in the evening sky, shining at magnitude +0.4

**31
MAY**



Conjunction between dwarf planet Ceres and Mars in Aquarius



**3
JUNE**



Globular cluster Messier 12 is well placed for observation in Ophiuchus at +6.1

**4
JUNE**



Mercury is at its greatest elongation east in the evening sky, shining at +0.4

**5
JUNE**



Globular cluster Messier 10 is well placed for observation in Ophiuchus at +6.6



**9
JUNE**



The Moon and Saturn make a close approach within 2°38' of each other in Capricornus



**13
JUNE**



Conjunction between the Moon and Mars in Aquarius

**13
JUNE**



The Moon and Mars make a close approach, passing within 2°32' of each other in Aquarius



Naked eye



Binoculars



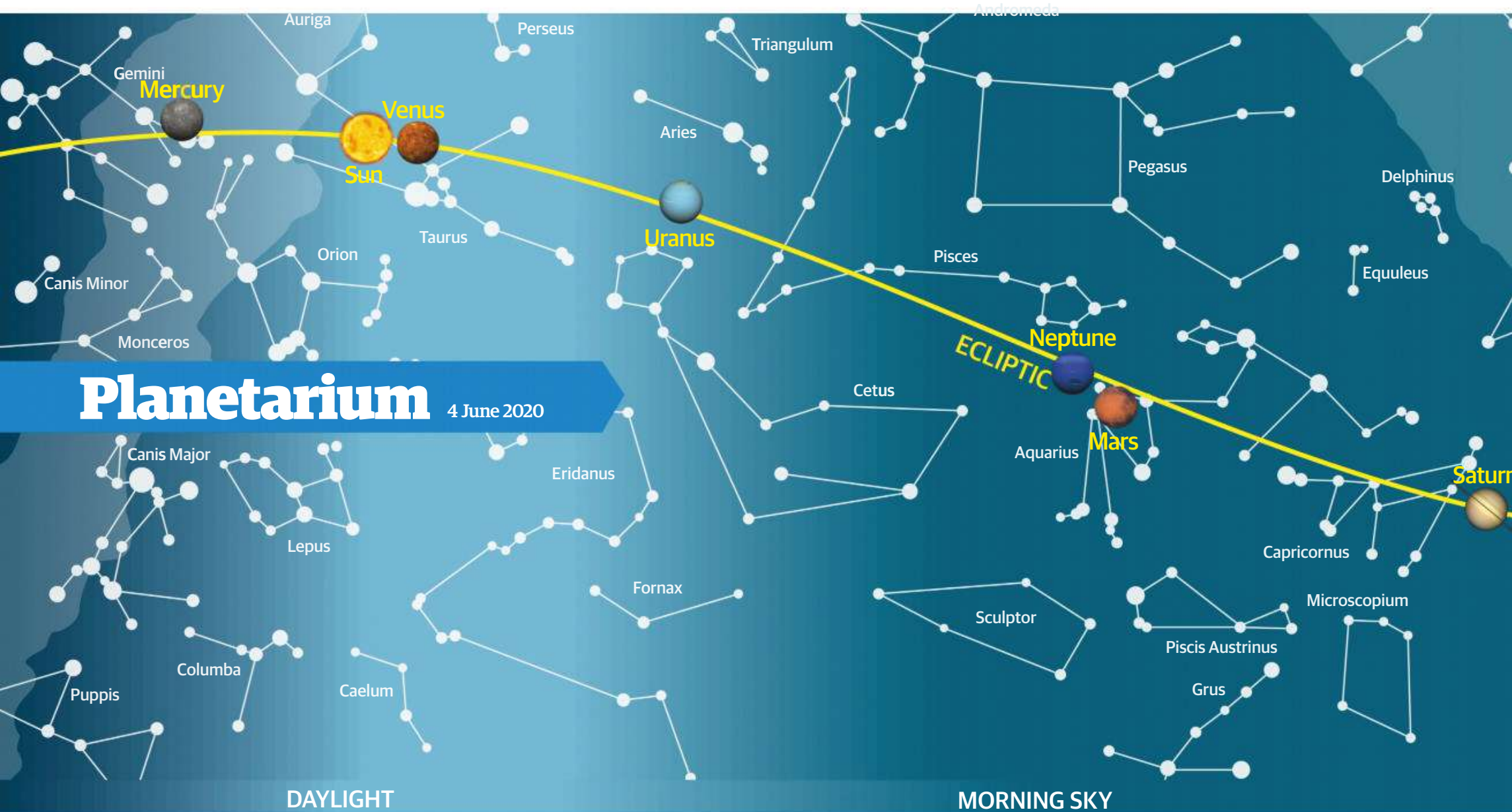
Small telescope



Medium telescope



Large telescope



Moon calendar

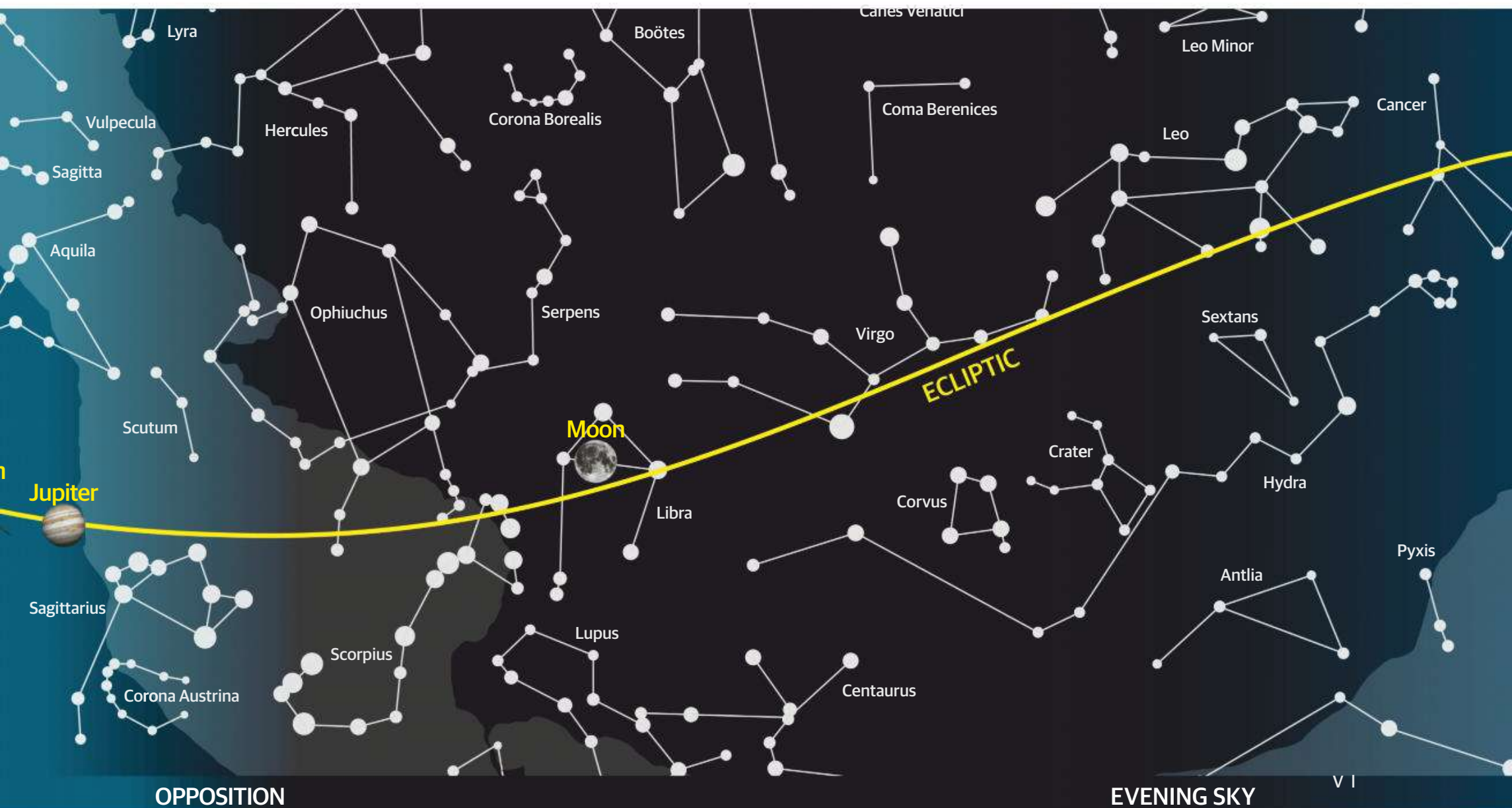
* The Moon does not pass the meridian on 4 June

21 MAY 1.7% 04:47 19:32	22 MAY NM 0.1% 05:08 20:42	23 MAY 0.6% 05:34 21:51	24 MAY 3.4% 06:06 22:57
25 MAY 8.2% 06:49 23:56	26 MAY 15.2% 07:42 ---	27 MAY 24.0% 00:45 08:47	28 MAY 34.3% 01:24 10:00
29 MAY 45.6% 01:56 11:19	30 MAY FQ 57.4% 02:21 12:40	31 MAY 68.9% 02:43 14:02	
1 JUN 79.5% 03:03 15:25	2 JUN 88.5% 03:22 16:49	3 JUN 95.1%* 03:43 18:14	4 JUN FM ---%* 04:07 19:39
5 JUN 99.0% 04:37 21:01	6 JUN 96.3% 05:15 22:15	7 JUN 98.0% 06:03 23:17	
8 JUN TQ 93.5% 07:01 ---	9 JUN 86.9% 00:05 08:08	10 JUN 78.8% 00:42 09:19	11 JUN 69.7% 01:09 10:30
12 JUN 60.1% 01:31 11:40	13 JUN 50.2% 01:49 12:48	14 JUN 40.4% 02:06 13:55	
15 JUN 31.1% 02:21 15:02	16 JUN NM 22.4% 02:36 16:09	17 JUN 14.8% 02:53 17:17	18 JUN 8.4% 03:12 18:27

% Illumination
Moonrise time
Moonset time

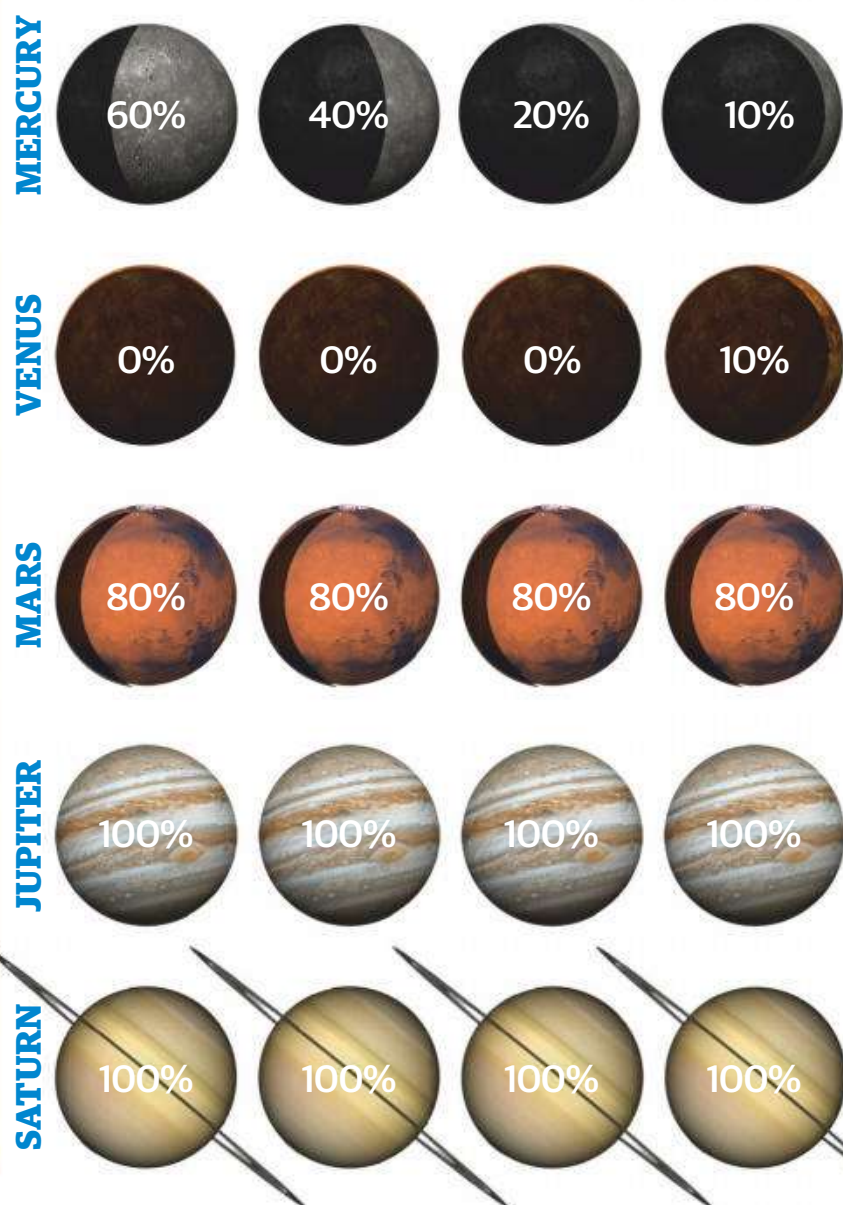
FM Full Moon
NM New Moon
FQ First quarter
TQ Third quarter

All figures are given for 00h at midnight (local times for London, UK)



Illumination percentage

28 MAY 4 JUNE 11 JUNE 18 JUNE



Planet positions

All rise and set times are given in BST

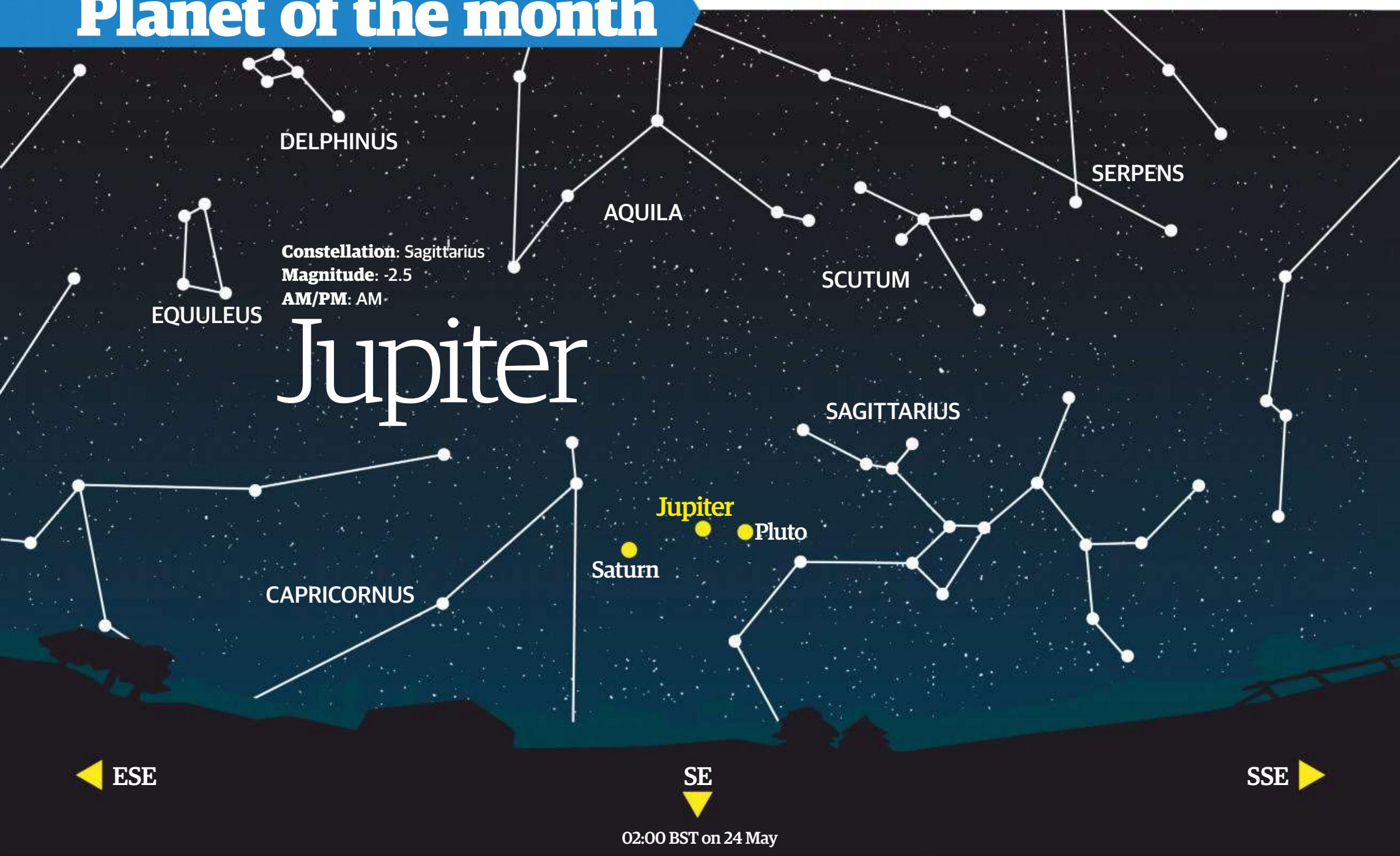
	Date	RA	Dec	Constellation	Mag	Rise	Set
MERCURY	21 MAY	05h 05m 04s	+24°58'28"	Taurus	-0.7	05:39	22:36
	28 MAY	05h 54m 09s	+25°38'53"	Taurus	-0.2	05:55	23:03
	4 JUNE	06h 31m 21s	+24°52'38"	Gemini	+0.4	06:11	23:06
	11 JUNE	06h 54m 37s	+23°15'05"	Gemini	+1.1	06:19	22:50
	18 JUNE	07h 02m 16s	+21°19'14"	Gemini	+2.3	06:12	22:17
VENUS	21 MAY	05h 17m 01s	+26°22'50"	Taurus	-4.3	05:40	22:59
	28 MAY	05h 04m 10s	+24°50'23"	Taurus	-4.0	05:12	22:07
	4 JUNE	04h 46m 41s	+22°47'43"	Taurus	-3.7	04:42	21:07
	11 JUNE	04h 29m 57s	+20°36'51"	Taurus	-4.0	04:13	20:08
	18 JUNE	04h 18m 44s	+18°47'36"	Taurus	-4.3	03:46	19:17
MARS	21 MAY	22h 30m 39s	-11°36'54"	Aquarius	+0.1	02:30	12:38
	28 MAY	22h 48m 42s	-10°01'02"	Aquarius	+0.0	02:12	12:37
	4 JUNE	23h 06m 21s	-08°23'58"	Aquarius	-0.1	01:54	12:36
	11 JUNE	23h 23m 38s	-06°46'39"	Aquarius	-0.2	01:35	12:34
	18 JUNE	23h 40m 28s	-05°10'09"	Aquarius	-0.3	01:16	12:31
JUPITER	21 MAY	19h 55m 53s	-20°57'18"	Sagittarius	-2.5	00:51	09:09
	28 MAY	19h 54m 59s	-21°00'57"	Sagittarius	-2.6	00:23	08:41
	4 JUNE	19h 53m 27s	-21°06'16"	Sagittarius	-2.6	23:50	08:11
	11 JUNE	19h 51m 20s	-21°13'07"	Sagittarius	-2.6	23:21	07:41
	18 JUNE	19h 48m 41s	-21°21'13"	Sagittarius	-2.7	22:52	07:09
SATURN	21 MAY	20h 15m 29s	-19°56'03"	Capricornus	+0.5	01:04	09:35
	28 MAY	20h 14m 52s	-19°58'42"	Capricornus	+0.4	00:36	09:07
	4 JUNE	20h 13m 57s	-20°02'20"	Capricornus	+0.4	00:08	08:38
	11 JUNE	20h 12m 45s	-20°06'50"	Capricornus	+0.3	23:36	08:09
	18 JUNE	20h 11m 17s	-20°12'06"	Capricornus	+0.3	23:07	07:39



This month's planets

Jupiter is not only the king of the Solar System, but the ruler of the dawn sky alongside Mars and Saturn

Planet of the month



While many sky-watchers and amateur astronomers will still be focusing their attention on Venus shining in the evening sky, there is another planetary treat to enjoy in the sky before sunrise. Early risers will see Jupiter, the largest planet in the Solar System, as a very bright 'morning star' throughout this month. This giant world, so huge it could contain over a thousand Earths with room to spare, can be found shining above the southeastern horizon in the early hours, lingering near the Sagittarius-Capricornus border.

At the start of our observing period Jupiter will be rising around 01:30, and as the weeks pass its visibility will improve. By mid-June it will be rising well before midnight and will technically become an evening object.

Through the month ahead Jupiter will be an easy naked-eye target, one of a chain of naked-eye planets stretched across the southeastern sky like beads on a wire. To Jupiter's left you'll find the Ringed Planet, Saturn, noticeably fainter than Jupiter and shining with more of a warm, yellow hue, and further over to the left and lower in the sky Mars will be shining brightly with its characteristic orange colour.

In photographs taken by the famous Hubble Space Telescope and before that by the Voyager and Galileo space probes, Jupiter's surface is shown criss-crossed by multiple light and dark bands of cloud. Red, brown and orange storms whirl around and past each other, and streamers of garishly coloured gas, teased out by strong upper-

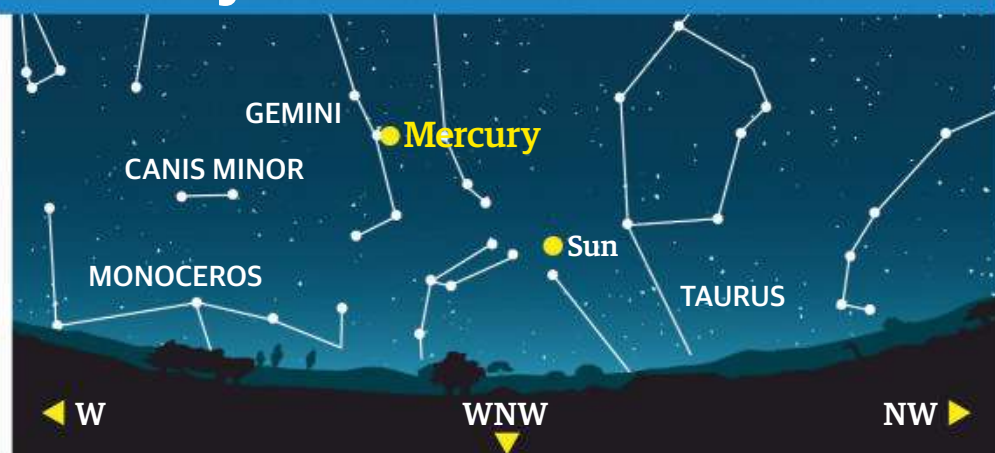
atmosphere winds, can also be seen. The largest amateur telescopes will resolve some of these features, though obviously in less detail. However, even a simple pair of binoculars will be more than good enough to show you Jupiter's four largest moons - the so-called Galilean Moons named after their discoverer, Galileo - looking like tiny pin-prick stars close to Jupiter itself.

During the month ahead Jupiter won't just have company of the planetary kind either. On 8 June early risers will be rewarded with the sight of the giant planet shining just nine degrees to the upper left of a very pretty almost-full Moon, and the following morning the giant planet will be shining less than six degrees to the Moon's upper right, both great observing opportunities.



This month's planets

Mercury 20:00 BST on 17 June



Constellation: Taurus

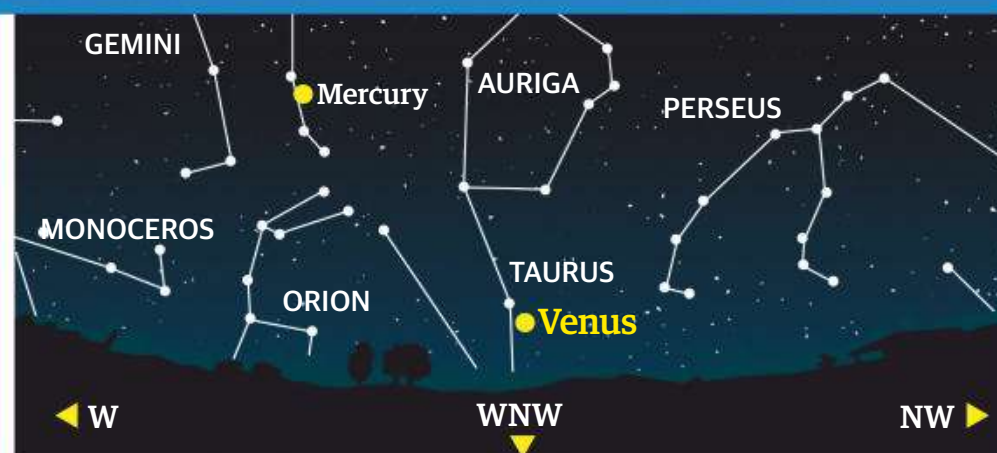
Magnitude: -0.6

AM/PM: PM

At the start of our observing period Mercury will be a copper-hued naked-eye 'evening star' low in the

northwest right after sunset, shining very close to the much brighter electric blue-white Venus. On 21 May the two worlds will be just over a degree apart, with Venus directly above Mercury.

Venus 20:00 BST on 5 June



Constellation: Taurus

Magnitude: -4.2

AM/PM: PM

Having dominated the evening twilight for the past few months, Venus is still a bright 'evening star',

visible low in the northwest soon after sunset, but it is way past its best now. By the end of May Venus will be hard to see in the twilight, and by the end of June's first week will be lost in the Sun's glare.

Mars 03:00 BST on 17 June



Constellation: Aquarius

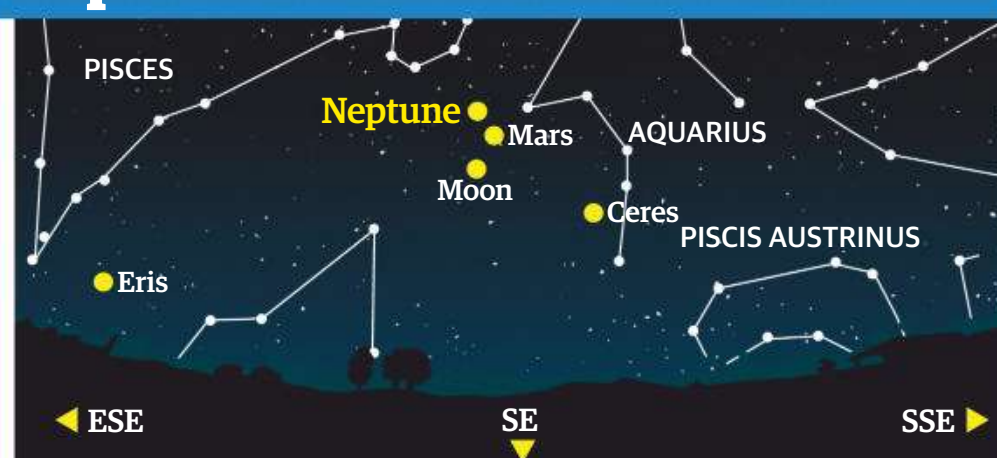
Magnitude: +0.1

AM/PM: AM

Gearing up for its opposition in October, the Red Planet is visible in the predawn sky this month,

shining low in the southeast. Although Mars brightens noticeably as the days pass and it climbs higher up into the sky, it's not visible for long before sunrise, so you'll need to make the most of it.

Neptune 04:00 BST on 13 June



Constellation: Aquarius

Magnitude: +7.9

AM/PM: AM

Neptune is a morning object this month, roughly halfway between Uranus and Saturn. Unfortunately

it will be so small and so faint that you'll need a telescope to see it, and even then it will be hard to pick out from the background stars unless you note its motion over several different mornings.

Saturn 03:00 BST on 12 June



Constellation: Capricornus

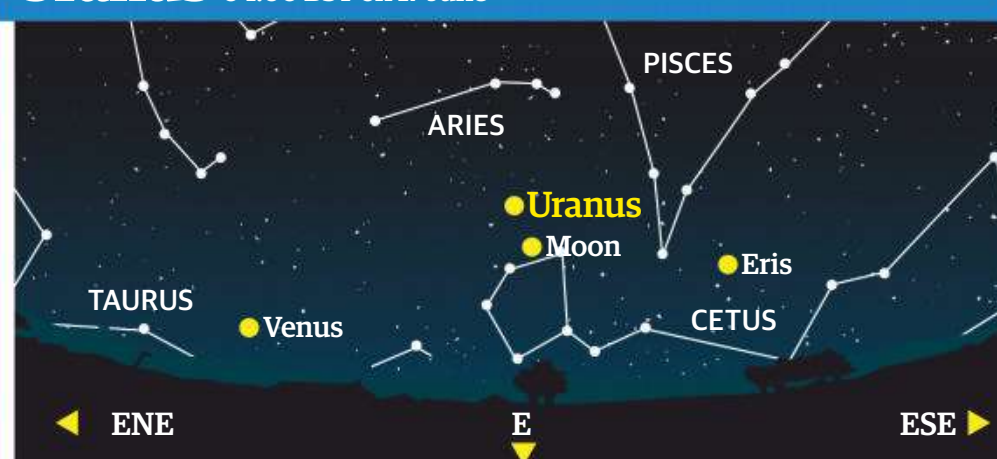
Magnitude: +0.5

AM/PM: AM

Saturn can be found in the morning sky this coming month, shining low in the southeast before dawn

close to the planet Jupiter. It will be easy to tell the two apart because Saturn will be fainter and more of a warm yellow colour. The Moon will be shining close to Saturn before sunrise on the morning of 9 June.

Uranus 04:00 BST on 17 June



Constellation: Aries

Magnitude: +5.9

AM/PM: N/A

It's technically a naked-eye object, but at the start of our observing period it will lie too close to the Sun

in the sky for that to be possible; it will be lost in the Sun's glare. As the weeks pass Uranus will slowly pull away from the Sun and its visibility will improve as it moves into a darker part of the sky.



STARGAZER

© NASA

Top tip!

The full Moon can be a dazzling sight through a telescope, so don't look at it for longer than a couple of minutes at a time. You can cut down its glare with an eyepiece 'Moon filter'.

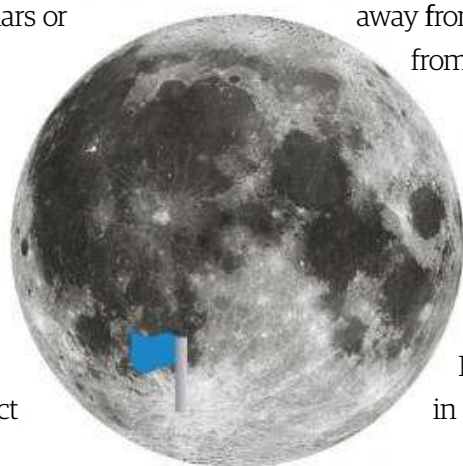
Moon tour

Tycho

Find one of the most famous craters on the lunar surface; the star of one of the most famous science-fiction films ever made

Like the craters Copernicus and Plato, and other features such as the Apennine Mountains and Sinus Iridum, Tycho is a true lunar celebrity. Named after the famous Danish astronomer Tycho Brahe, a larger-than-life character best known for wearing a gold nose after his own was cut off in a duel, it has an even greater claim to fame: it featured in the classic 1960s sci-fi film *2001: A Space Odyssey*.

Unlike some lunar features, finding Tycho is almost embarrassingly easy. If you look down towards the bottom of the lunar disc when the Moon is full, around 4 June, rising mid-evening in the southeast, if you have good eyesight you should see what looks like a bright spot there. Your binoculars or small telescope will show that light spot has lots of narrow, bright lines radiating away from it. You'll see that some of them extend almost to the top of the disc. This feature is Tycho, and the bright lines are rays of debris which spread out from the crater when it was born in a stunningly violent meteorite impact



more than 100 million years ago. Any dinosaurs looking up at the Moon at that time must have been very puzzled.

Our modern space probes, lunar satellites and of course the observations made by the Moon-orbiting Apollo astronauts have allowed us to build up a very accurate picture of the nature of Tycho. The crater is 85 kilometres (52.8 miles) across and almost five kilometres (3.1 miles) deep. A central peak mountain rears up from the centre of the crater's hummocky, pitted floor which is almost two kilometres (1.2 miles) high. The longest debris rays radiating away from Tycho stretch more than 1,500 kilometres (932 miles) away from it, roughly the same distance as from London to Lisbon.

To see any detail within Tycho you'll have to wait until the crater is illuminated by the Sun at an angle, not from overhead. Then its appearance will change dramatically. By 30 May, with the Moon at first quarter and visible high in the southwest after sunset, it will

look like everyone's image of a crater - a pit with steep walls, a mountain peak jutting up out of its centre and rays of debris shooting away from it on all sides.

For the next couple of days after that Tycho will be at its very best, when the terminator of the waxing Moon silently sweeps over and past the crater. With the Sun's slanting rays illuminating Tycho at a steep angle, even a small telescope will reveal a wealth of detail inside it. High-magnification eyepieces will show you how the inside walls of the crater slope gently and are terraced too. They will also show you many mounds and hillocks of material spread across the floor. The crater's central peak will really stand out too.

If bad weather prevents you from observing Tycho, look online for the image taken by NASA's Lunar Reconnaissance Orbiter (LRO) in June 2011, showing how the slopes of Tycho's central peak are streaked with rock slides and scattered with huge stones. One enormous, single boulder the size of Buckingham Palace can be seen sitting right on its summit.

Whenever you look at it Tycho is a fascinating sight. It looks different every time you see it, never quite the same two nights running.



Naked eye & binocular targets

Use the tail of the Big Dipper to find two bright stars and a pair of beautiful star clusters

Arcturus (Alpha Boötis)

This magnitude -0.05 orange star is the brightest star in the Northern Hemisphere and the fourth-brightest star in the whole sky. Approximately 36.7 light years away, it is the closest giant star to Earth. Find it by following the 'arc' of the Big Dipper's handle.

Corona Borealis

Messier 3

One of the best globular clusters in the sky, Messier 3 is a ball of around 300,000 stars. At sixth magnitude it is visible to the naked eye under a very dark sky. More than 34,000 light years distant, it is further away from us than the centre of the Milky Way.

Serpens Caput

Boötes

Canes Venatici

Messier 5

Messier 5 is one of the most beautiful globular clusters, but is often overlooked because the brighter and more famous M13 is nearby. At magnitude +5.6 it is a lovely sight in binoculars and small telescopes. It contains around 100,000 stars.

Corona Berenices

Virgo

Spica (Alpha Virginis)

A dazzling star in the constellation of Virgo, magnitude +0.98 Spica is only the 15th-brightest star in the sky. Some 250 light years away from Earth, it is actually a double star with components that orbit each other every four days.

Porrina (Gamma Virginis)

About 38 light years away from us, magnitude +2.7 Porrina is a binary star. A small telescope is powerful enough to split its almost-identical members, which orbit each other in a highly elliptical path every 169 years. Find Spica by 'driving a spike from Arcturus'.



Deep sky challenge

The Great Bear's faint fuzzies

With the Big Dipper laying flat above the western horizon at sunset, June nights are perfect for exploring the hidden treasures of Ursa Major

Think of the constellation of Ursa Major and you probably think of the seven bright naked-eye stars that make up the famous asterism 'the Big Dipper' - or 'the Plough', or whatever you want to call it - including the best-known double star in the sky, Mizar, and the twin 'pointers' that point the way to Polaris, the Pole Star, in neighbouring Ursa Minor. But this much-loved constellation - stretched out across the western horizon as

darkness falls on these early summer nights - has a lot more to offer.

Lurking inside the boundaries of Ursa Major are many deep-sky objects unfamiliar to - and unobserved by - many telescope owners. There are plenty of galaxies for observers who like the challenge of hunting down those faint, distant star cities, and some brighter nebulae within our own Milky Way galaxy too.

The close pair of M81 and M82 is much loved by owners of small telescopes, but only larger instruments will show detail in the arms and centres of these far-off galaxies. The Owl Nebula, or M97, is very popular with observers of planetary nebulae - the glowing shells of dying stars - because it really does resemble the face of a wise old owl when seen through a high-power eyepiece in a large telescope.





Bode's Galaxy
(Messier 81)



© NASA/ESA & Hubble

Messier 109



© NASA/ESA & Hubble

"The close pair of M81 and M82 is much loved by owners of small telescopes, but only larger instruments will show detail in the arms and centres of these far-off galaxies"

1 Messier 108

This barred-spiral galaxy is 45 million light years away. Shining at magnitude +10, it is visible as a featureless elongated smudge in 6" telescopes. Larger apertures will reveal some subtle mottling.

2 Messier 109

Magnitude +9.7, this barred-spiral galaxy is merely a small, pear-shaped blur in small telescopes. Instruments of six inches and larger will show the subtle glow of its spiral arms.

3 The Owl Nebula (Messier 97)

Faint and with a low surface brightness, you will need at least a medium-aperture telescope to see the two dark 'eyes' of this magnitude +9.8 planetary nebula.

4 Messier's Mistake (Messier 40)

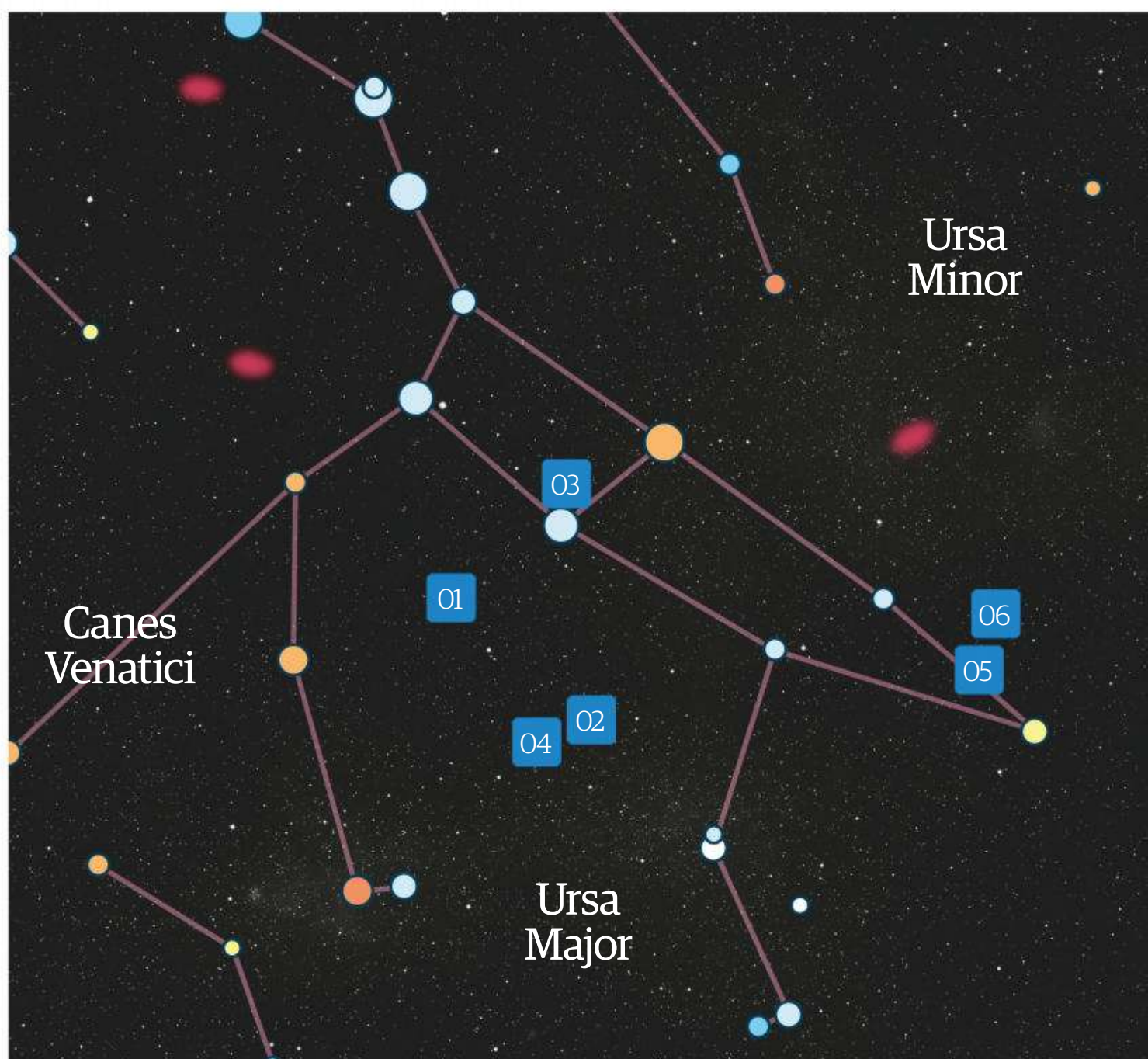
This object is a strange curiosity in Messier's catalogue because it is not a galaxy, nebula or cluster but a close pair of stars. It is just an optical 'line-of-sight' double rather than a genuine binary.

5 Bode's Galaxy (Messier 81)

At magnitude +6.8 this spiral galaxy is bright enough to be visible in binoculars as a tiny smudge, but it takes telescopes of six inches and up to show its beautiful spiral arms and bright core.

6 Cigar Galaxy (Messier 82)

Just over half a degree away from M81, M82, the 'Cigar Galaxy', is much smaller and fainter than its more obvious neighbour. A large telescope will reveal light and dark patches along it.





The Northern Hemisphere

Late-night astronomers are treated to a stunning selection of deep-sky objects

Summer is officially here, with the solstice falling on 20 June. The short summer nights are warm, but don't leave much time for observing. Still, this shouldn't put you off, as there's plenty around to see. The constellation of Boötes rides high with orange-hued Arcturus to the south after sunset.

Look out for the brilliant star Vega in the constellation Lyra, not far from the celebrated Ring Nebula (M57), a planetary nebula that looks like a smoke ring through a small telescope. Towards the southern horizon are the constellations of Sagittarius and Scorpius, where the centre of our galaxy is located. Here the Milky Way is at its densest, with plenty of stars and star clusters for you to seek out, such as Messier 4, 6, 7 and 25.

Using the sky chart

This chart is for use at 22:00 (BST) mid-month and is set for 52° latitude.

- 01 Hold the chart above your head with the bottom of the page in front of you.
- 02 Face south and notice that north on the chart is behind you.
- 03 The constellations on the chart should now match what you see in the sky.



Magnitudes

- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- Fainter
- Variable star

Spectral types

- | | |
|-------|-----|
| • O-B | • G |
| • A | • K |
| • F | • M |

Deep-sky objects

- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies

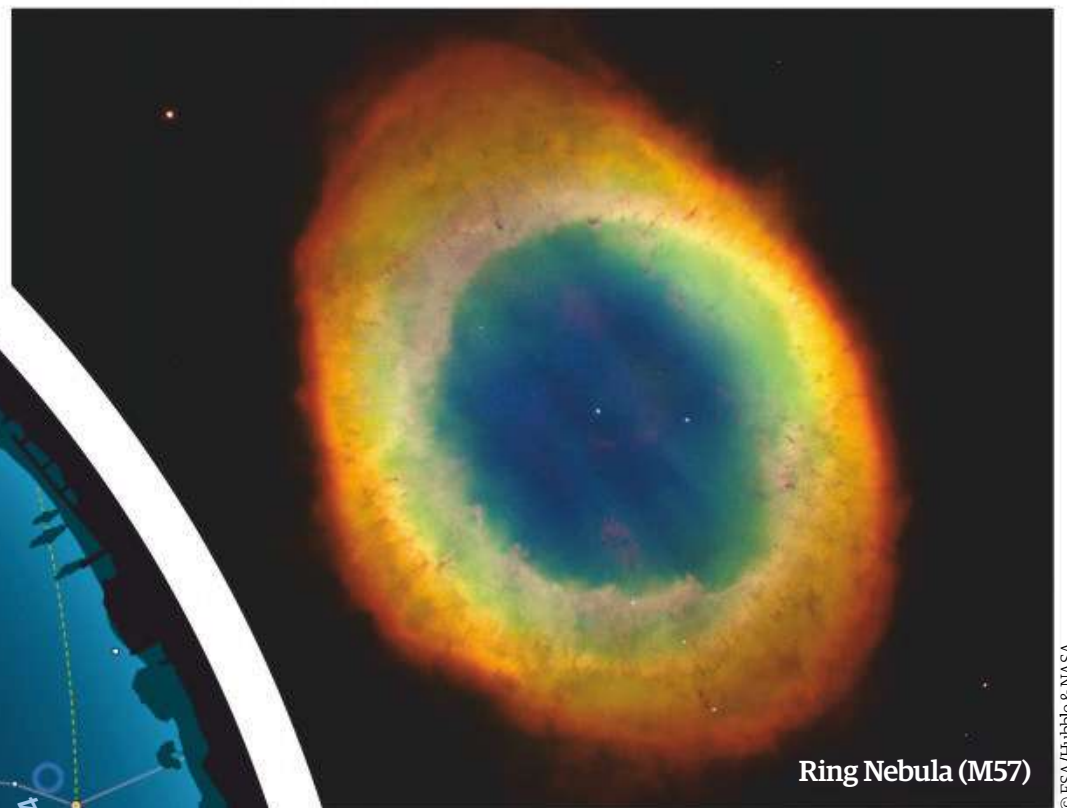


Observer's note:

The night sky as it appears on 17 June 2020 at approximately 22:00 (BST)

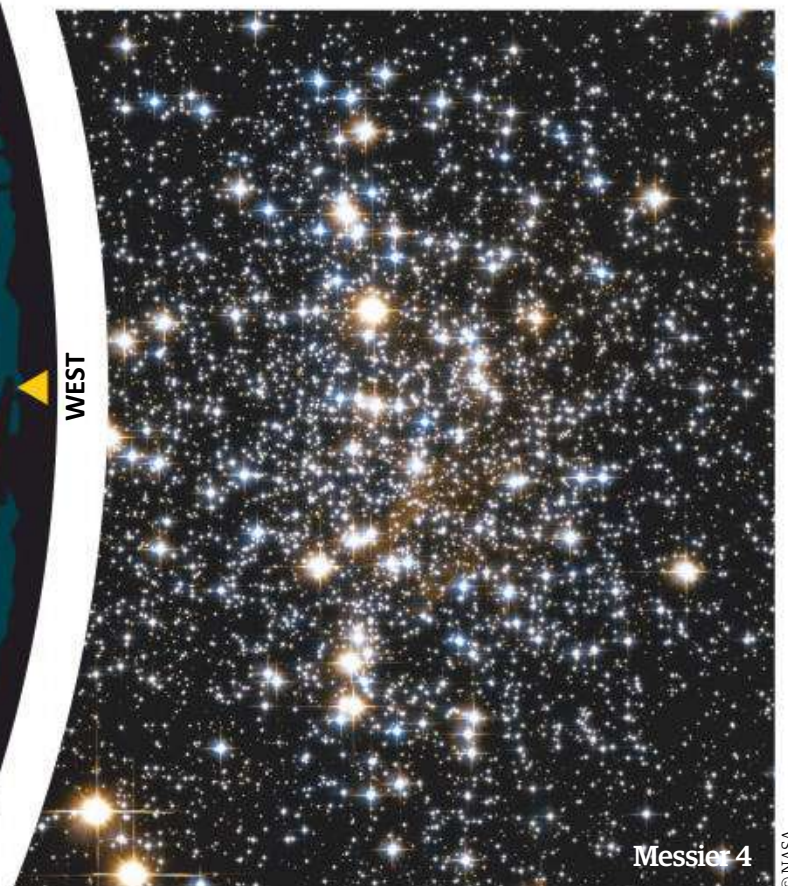


The Northern Hemisphere



Ring Nebula (M57)

© ESA/Hubble & NASA



Messier 4

© NASA



Arcturus (Alpha Boötis)

© NASA

JUNE 2020



Celestron CPC 800 GPS (XLT)

Ideal for the serious astrophotographer, this superb instrument is a must-have for those looking to upgrade from a beginner scope



Telescope advice

Cost: £2,225 (approx. \$2,732)

From: David Hinds Ltd.

Type: Schmidt-Cassegrain

Aperture: 8"

Focal length: 80"

Best for...



Intermediate



Large budget



Planetary viewing



Lunar viewing



Deep-sky objects



Astrophotography

With the CPC 800, you certainly get what you pay for. An incredibly well-made instrument, this beautifully presented telescope is ideal for those looking to upgrade from a beginner's telescope or for those looking for an all-rounder that allows astronomers to get their teeth into some serious astrophotography, and on first impressions the telescope appears to be very robust.

The CPC 800 may look daunting to set up to some, but thankfully Celestron has provided in-depth instructions for fuss-free construction, leaving the user fully guided through the process. The scope will take more than a few minutes to set up, but this is to be expected - especially if you have never put together a computerised instrument. On the whole we do think that the general set up is easy, thanks to the excellent design.

Due to the excellent weather throughout March and April, we didn't have to wait too long to test the CPC 800's mettle on a variety of night-sky targets. As expected - and since it is comprised mostly of steel - the CPC 800 is quite heavy, weighing in at 48 kilograms (106 pounds). While the fork mount makes lifting the scope that touch easier over others, we recommend getting someone to help you carry it to your chosen observing site or transporting it in a car. While

it's quite easy to see the heftiness as a negative, many - if not all - astronomers will be thankful of this: even with a prevalent icy breeze, the telescope stood impressively still. With the constellations of Ursa Major, Leo, Virgo and Ursa Minor above us in the sky, we couldn't wait to view their many deep-sky treasures using the eight-inch aperture of the CPC 800.

Before we could start our tour the night sky, however, we had to use the SkyAlign technology in order to align the telescope for what Celestron states is a "fast and easy alignment process". We couldn't have been more impressed with this feature. Simply pick three bright objects in the sky - these can be the Moon, planets or stars - and the telescope's computer system does the work for you. While the experience was a painless one, we do think that a red dot finder during the alignment process would have been more useful - terrestrial finderscopes, of which this scope possesses an 8x50, can often be problematic. We discovered that the telescope's GPS was turned off, but it took no more than a few minutes for the system to figure out our position.

Users of the telescope also need to remember to set daylight savings time.

Once set up the telescope operates

Above: The CPC 800 is supplied with a 40mm eyepiece that gives a magnification of 51x

Right: The StarBright XLT coating ensures that targets are crystal clear and bright when viewed through the eyepiece





“Makes anything from planetary to deep-sky objects a joy to observe”

relatively flawlessly, and on the whole is incredibly easy to use. Using the NexStar hand control we instructed the CPC 800 to slew to spiral galaxy Messier 81, also known as Bode's Galaxy, in the constellation of Ursa Major. The telescope's motors are impressively quiet, and we didn't notice too much shaking of the tripod as the fork mount turned the tube towards our target.

The telescope is supplied with a 40mm eyepiece which is of beautiful quality and supplies a magnification of 51x. In order to view a vaster selection of targets you will need to accessorise the CPC 800 with eyepieces that supply low, medium and high power. Plugging the supplied eyepiece into the holder, we got an impressively clear view of this 12-million-light-year-distant spiral, with the CPC 800 picking it out as a small oval. Bringing the view into focus, the focus knob isn't as smooth as we would have liked but it did the job nonetheless. We waited for the Pinwheel Galaxy, also known as Messier 101, to become visible later on into the early hours of the morning. We were not disappointed with the view of this stunning face-on spiral.

The StarBright XLT coating provides bright, clear views of a variety of targets, making anything from planetary to deep-sky objects a joy to observe. With its database of roughly 40,000 objects, observers will find that they can spend more time observing rather than finding objects, something that's useful when clouds threaten to roll in and spoil an observing session.

It wouldn't be a complete observing session without locating other members of our Solar System, and Jupiter was a stunning sight through the CPC 800 in the small hours. Using the supplied 40mm eyepiece the gas giant appeared as a small but crystal-clear disc with the Galilean moons - Io, Europa, Ganymede and Callisto - showing up as small pinpoints of light. Allowing our eyes to adjust to the view of the planetary king, we could make out its atmospheric bands. The star diagonal is well-orientated, which allows comfortable viewing for long periods of time.

While the Celestron CPC 800 might make a dent in the savings of many interested buyers, we have to say that given the telescope's build, general operation and the state-of-the-art technology it offers, it's worth every pound, especially if you're looking for an instrument to replace a basic scope. The CPC 800 gets a massive thumbs up from us!

Right: While the tube vibrated as it slewed from one target to the next, the set-up is very sturdy

The NexStar computer control technology takes the fuss out of finding a variety of targets with its database of roughly 40,000 night-sky objects



Deke Slayton

One of the original Mercury 7 astronauts faced some disappointment, but that didn't stop him from getting into space

Donald "Deke" Slayton was a determined character who strived to journey into space, overcoming medical issues while helping choose the Apollo astronauts that would make history.

Born on 1 March 1924 in Sparta, Wisconsin, Slayton took to aviation at an early age, enrolling as an aviation cadet on his 18th birthday. After receiving his wings he spent a lot of time flying combat missions throughout Europe and then the Ryukyu Islands before Japan's surrender in 1945. After the end of World War II Slayton was discharged from the Air Force, giving him the time to gain a bachelor's degree in aeronautical engineering from the University of Minnesota.

In 1951 he was recalled to aviation duty for a further four years. It was at this time that the United States was entering its Space Race with the Soviet Union, the two great nations going head to head to see who could conquer the cosmos first. It was around 1959 when the US began ironing out the details of Project Mercury, which was the nation's plan to get its first set of astronauts into space and achieve low-Earth orbit. After a series of applications, examinations and invitations, Slayton would be asked to join NASA's Space Task Group for Project Mercury.

On 9 April 1959 NASA announced its famous Mercury 7, the astronauts that would take the nation forwards into the final frontier. After the announcement, the hard work began. Their training consisted of a little of everything, from introductory space science lessons to scuba diving. However, each of the seven was also trained in a specialist subject which was related to the mission. In the case of Slayton, he got to know the ins and outs of the Atlas missile that would jettison them into space.

When the time came for action, all of the Mercury 7 were prepped and ready to show the world what they could do. Slayton was due to be the first American in orbit around Earth. However, in the previous flight of Friendship 7, John Glenn's suborbital flight became an orbital flight, meaning Slayton would become the second American to reach orbital status.

Unfortunately, prior to the launch medical professionals identified a heart condition known as idiopathic atrial fibrillation, meaning Slayton



had an erratic heart rate. This meant that his backup, Scott Carpenter, would fly the mission instead. Sadly his condition left him unable to fly any mission in the Mercury, Gemini or Apollo programs, but Slayton was still a Herculean figure during this time. He began coordinating the responsibilities for manned space flights. He managed to do all this planning while also joining in training, being constantly monitored throughout the process. In 1966 he became director of flight crew operations and was key in picking the Apollo crews that would journey successfully to the Moon.

Slayton would eventually achieve his personal goal of reaching space, however. He finally launched on 15 July 1975 when he participated in the first rendezvous between American and Soviet spacecraft as part of the Apollo-Soyuz Test Project. This wasn't without sacrifice, as he had to change his lifestyle dramatically. This included quitting smoking, daily exercise, putting down the coffee permanently and ensuring an increase in vitamin intake - all changes he was willing to make to finally achieve his goal. This just goes to show that after years of hard work and dedication, anyone can eventually have their crowning moment.

"Slayton was due to be the first American in orbit around the Earth"

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The Eurofighter Typhoon is a twin-engine, canard-delta wing, multi-role fighter. It was designed originally as an air superiority fighter and is manufactured by a consortium of Airbus, BAE Systems and Leonardo. One of the world's most capable fighter aircraft, it possesses all the attributes that made the Spitfire so successful in combat and is the most effective air defence fighter to ever serve with the RAF.

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£89.99

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"The optics were so good....
the review instrument
certainly delivered in every
important respect"
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SKYHAWK-1145P (EQ1)

114mm f/4.4 PARABOLIC REFLECTOR

EXPLORER-130 (EQ2)

130mm f/6.92 REFLECTOR

"This telescope made observing
the night sky enjoyable....great
views coupled with ease of use"
BBC SKY AT NIGHT MAGAZINE

EXPLORER-150P (EQ3-2)

150mm f/5
PARABOLIC REFLECTOR

"Good for advanced observing...
Saturn was a stunning sight"
BBC SKY AT NIGHT MAGAZINE

SRP
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COMMEDED
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EXPLORER-150PL (EQ3-2)

150mm f/8 PARABOLIC
REFLECTOR

SRP
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EXPLORER-200P (EQ5)

200mm f/5 PARABOLIC REFLECTOR

"Passed all our tests with flying
colours and was a delight to use
both optically and mechanically"
BBC SKY AT NIGHT MAGAZINE

Sky at Night
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WINNER

SRP
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SKYLINER-150P CLASSIC

153mm f/7.8 PARABOLIC DOBSONIAN

SRP
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"Turning to Saturn, the view really took our
breath away....The Skyliner was a joy to use"
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COMMEDED
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203mm f/5.9 PARABOLIC DOBSONIAN

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254mm f/4.7 PARABOLIC
DOBSONIAN

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INFINITY-76P CHILDREN'S

76mm f/4 PARABOLIC REFLECTOR

SRP
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SRP
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DOBSONIAN

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76mm f/4 DOBSONIAN

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130mm f/5 PARABOLIC DOBSONIAN

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